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Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Point Source Category. Volume 1 General Development Document

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Volume I

General Development Document

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for
EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS
for the
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

GENERAL DEVELOPMENT DOCUMENT

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This development document for nonferrous metals manufacturing (phase I) consists of three volumes, a general development document and two volumes of subcategory-specific supplements. The Agency intends to modify the General Development Document, as necessary, and produce additional volumes of subcategory-specific supplements in order to support limitations and standards for additional nonferrous metals manufacturing (phase II) subcategories as they are proposed and promulgated.

TABLE OF CONTENTS

Section Page

I SUMMARY 1

EXISTING REGULATIONS. 1

METHODOLOGY 1

TECHNOLOGY BASIS FOR LIMITATIONS AND STANDARDS. 7

II CONCLUSIONS 11

III INTRODUCTION. 69

PURPOSE AND AUTHORITY 69

PRIOR EPA REGULATIONS 71

Primary Aluminum Subcategory. 71
Secondary Aluminum Subcategory. 71
Primary Copper Smelting 71
Primary Electrolytic Copper Refining. 72
Secondary Copper. 72
Primary Lead. 72
Primary Zinc. 72
Metallurgical Acid Plants 72

METHODOLOGY 73

Approach of Study 73
Data Collection and Methods of Evaluation . . 74

GENERAL PROFILE OF THE NONFERROUS METALS MANUFACTURING CATEGORY. 77

IV INDUSTRY SUBCATEGORIZATION. 83

SUBCATEGORIZATION BASIS 83

Metal Products, Co-Products, and By-Products. 85
Raw Materials 85
Manufacturing Processes 85
Product Form 86
Plant Location. 86
Plant Age 86

TABLE OF CONTENTS (Continued)

Section Page

Plant Size 87
Air Pollution Control 87
Meteorological Conditions 87
Solid Waste Generation and Disposal 88
Number of Employees 88
Total Energy Requirements 88
Unique Plant Characteristics. 88

PRODUCTION NORMALIZING PARAMETERS 89

V WATER USE AND WASTEWATER CHARACTERISTICS. . . . 91

DATA SOURCES. 91

Historical Data 91
Data Collection Portfolios. 91
Sampling and Analysis Program 92

WATER USE AND WASTEWATER CHARACTERISTICS. . . 100

VI SECTION OF POLLUTANT PARAMETERS 103

RATIONALE FOR SELECTION OF POLLUTANT PARAMETERS. 104

DESCRIPTION OF POLLUTANT PARAMETERS 105

SUMMARY OF POLLUTANT SELECTION. 176

Pollutants Selected for Further Consideration by Subcategory. 177
Toxic Pollutants Not Detected 181
Toxic Pollutants Detected Below the Analytical Quantification Limit 198
Toxic Pollutants Detected in Amounts too Small to be Effectively Reduced by Technologies Considered in Preparing this Guideline 203
Toxic Pollutants Detected in the Effluent From Only a Small Number of Sources 205
Toxic Pollutants Detected but Present Solely as a Result of Their Presence in the Intake Waters. 208

TABLE OF CONTENTS (Continued)

Section Page

VII CONTROL AND TREATMENT TECHNOLOGY. 215

END-OF-PIPE TREATMENT TECHNOLOGIES. 215

MAJOR TECHNOLOGIES. 216

Activated Alumina Adsorption. 216
Ammonia Steam Stripping 217
Carbon Adsorption 219
Chemical Precipitation. 221
Advantages and Limitations. 226
Cyanide Precipitation 227
Granular Bed Filtration 229
Pressure Filtration 232
Settling. 234
Skimming. 236

MAJOR TECHNOLOLOGY EFFECTIVENESS. 238

L&S Performance - Combined Metals Data Base . 238
One Day Effluent Values 241
Average Effluent Values 244
Additional Pollutants 247
LS&F Performance. 249
Analysis of Treatment System Effectiveness. . 250
Ammonia Steam Stripping Performance 253
Activated Carbon Performance. 254

MINOR TECHNOLOGIES. 254

Flotation 254
Centrifugation. 257
Coalescing. 259
Cyanide Oxidation by Chlorine 260
Cyanide Oxidation by Ozone. 261
Cyanide Oxidation by Ozone with UV Radiation. 262
Cyanide Oxidation by Hydrogen Peroxide. . . . 263
Evaporation 264
Gravity Sludge Thickening 267
Ion Exchange. 268
Insoluble Starch Xanthate 271
Peat Adsorption 271
Membrane Filtration 273
Reverse Osmosis 274
Sludge Bed Drying 277
Vacuum Filtration 279

TABLE OF CONTENTS (Continued)

Section		Page
	IN-PLANT TECHNOLOGY	281
	Process Water Recycle	281
	Process Water Reuse	284
	Process Water Reduction	285
	Air Cooling of Cast Metal Products	286
	Dry Slag Processing and Granulation	286
	Dry Air Pollution Control Devices	287
	Good Housekeeping	288
VIII	COST, ENERGY, AND NONWATER QUALITY ASPECTS	345
	BASIS FOR COST ESTIMATION	345
	Sources of Cost Data	345
	Determination of Costs	345
	Investment (Capital) Cost Basis	346
	Annual Cost Basis	347
	TECHNOLOGY BASIS FOR COST DEVELOPMENT	351
	Recycle	351
	Steam Stripping	352
	Cyanide Precipitation	352
	pH Adjustment	355
	Chemical Precipitation, Sedimentation, Gravity Thickening, Vacuum Filtration	355
	Multimedia Filtration	357
	Activated Carbon Adsorption	358
	Activated Alumina Adsorption	359
	Reverse Osmosis, Evaporation	360
	NEW SOURCES	360
	COST METHODOLOGY FOR SPECIFIC PLANTS	361
	NONWATER QUALITY ASPECTS	361
	Air Pollution, Radiation, and Noise	362
	Solid Waste Disposal	362
	Energy Requirements	363
IX	EFFLUENT QUALITY ATTAINABLE THROUGH APPLICATION OF THE BEST PRACTICABLE CONTROL CURRENTLY AVAILABLE	377

TABLE OF CONTENTS (Continued)

Section		Page
TECHNICAL APPROACH TO BPT	377
MODIFICATIONS TO EXISTING BPT EFFLUENT LIMITATIONS	379
Primary Lead	380
Metallurgical Acid Plants	380
MODIFIED APPROACH TO STORMWATER	381
BPT OPTION SELECTION	383
Primary Lead	384
Primary Tungsten	384
Primary Columbium-Tantalum	384
Secondary Silver	385
Secondary Lead	385
EXAMPLES OF BUILDING BLOCK APPROACH IN DEVELOPING PERMITS	386
X	EFFLUENT QUALITY ATTAINABLE THROUGH APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE	395
TECHNICAL APPROACH TO BAT	396
Industry Cost and Pollutant Reduction Benefits of the Various Treatment Options	396
MODIFICATION OF EXISTING BAT EFFLUENT LIMITATIONS	399
Primary Aluminum	399
Secondary Aluminum	400
Primary Electrolytic Copper Refining	400
Primary Lead	401
Primary Zinc	401
Metallurgical Acid Plants	401
Modified Approach to Stormwater	401
BAT OPTION SELECTION	402

TABLE OF CONTENTS (Continued)

Section		Page
	Primary Aluminum	403
	Secondary Aluminum	404
	Primary Electrolytic Copper Refining	405
	Primary Lead	405
	Primary Zinc	406
	Metallurgical Acid Plants	406
	Primary Tungsten	407
	Primary Columbium-Tantalum	407
	Secondary Silver	408
	Secondary Lead	409
	REGULATED POLLUTANT PARAMETERS	409
	EXAMPLES OF BUILDING BLOCK APPROACH IN DEVELOPING PERMITS	410
XI	NEW SOURCE PERFORMANCE STANDARDS	419
	TECHNICAL APPROACH TO NSPS	419
	Modifications to Existing NSPS	421
	NSPS OPTION SELECTION	421
	Primary Aluminum	422
	Secondary Aluminum	422
	Primary Copper Smelting	422
	Primary Electrolytic Copper Refining	423
	Secondary Copper	423
	Primary Lead	423
	Primary Zinc	424
	Metallurgical Acid Plants	424
	Primary Tungsten	424
	Primary Columbium-Tantalum	425
	Secondary Silver	425
	Secondary Lead	425
XII	PRETREATMENT STANDARDS	427
	REGULATORY APPROACH	427
	MODIFICATIONS TO EXISTING PRETREATMENT STANDARDS	429

TABLE OF CONTENTS (Continued)

Section Page

Primary Aluminum. 430
Secondary Aluminum. 430
Secondary Copper. 430

OPTION SELECTION. 431

Primary Aluminum. 432
Secondary Aluminum. 432
Primary Copper Smelting 433
Primary Electrolytic Copper Refining. 433
Secondary Copper. 433
Primary Lead. 433
Primary Zinc. 434
Metallurgical Acid Plants 434
Primary Tungsten. 435
Primary Columbium-Tantalum. 435
Secondary Silver. 436
Secondary Lead. 437

XIII BEST CONVENTIONAL POLLUTANT CONTROL TECHNOLOGY. 441

XIV ACKNOWLEDGEMENTS. 445

XV REFERENCES. 447

XVI GLOSSARY. 465

LIST OF TABLES

Table | | Page
I-1 CURRENTLY PROMULGATED LIMITATIONS AND STANDARDS - NONFERROUS METALS MANUFACTURING . . 10

II-1 PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 12

II-2 PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 13

II-3 PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 15

II-4 PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 17

II-5 PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 20

II-6 PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 21

II-7 PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 23

II-8 PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 24

II-9 PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 26

II-10 PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 27

LIST OF TABLES (Continued)

Table		Page
II-11	PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY	28
II-12	PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY	29
II-13	PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY	31
II-14	PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY	33
II-15	PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY	39
II-16	PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY	41
II-17	PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY	43
II-18	PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY	44
II-19	PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY	45
II-20	PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY	46
II-21	PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY	47

LIST OF TABLES (Continued)

Table | Page

II-22 PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 48

II-23 PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 50

II-24 PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 52

II-25 PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY 55

II-26 BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY. 56

II-27 BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY. 58

II-28 BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY. 59

II-29 BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY. 60

II-30 BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY. 61

II-31 BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY. 62

II-32 BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY. 63

LIST OF TABLES (Continued)

Table		Page
II-33	BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY.	64
II-34	BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY.	65
II-35	BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY.	67
III-1	CURRENTLY PROMULGATED LIMITATIONS AND STANDARDS NONFERROUS METALS MANUFACTURING	80
III-2	NONFERROUS METALS CONSIDERED FOR REGULATION UNDER PHASE II	81
III-3	BREAKDOWN OF DCP RESPONDENTS BY TYPE OF METAL PRODUCED.	82
V-1	DISTRIBUTION OF SAMPLED PLANTS IN THE NONFERROUS METALS MANUFACTURING CATEGORY BY SUBCATEGORY. .	101
VI-1	LIST OF 129 TOXIC POLLUTANTS.	209
VII-1	pH CONTROL EFFECT ON METALS REMOVAL	289
VII-2	EFFECTIVENESS OF SODIUM HYDROXIDE FOR METALS REMOVAL	290
VII-3	EFFECTIVENESS OF LIME AND SODIUM HYDROXIDE FOR METALS REMOVAL.	291
VII-4	THEORETICAL SOLUBILITIES OF HYDROXIDES AND SULFIDES OF SELECTED METALS IN PURE WATER . . .	292
VII-5	SAMPLING DATA FROM SULFIDE PRECIPITATION-SEDIMENTATION SYSTEMS	293
VII-6	SULFIDE PRECIPITATION-SEDIMENTATION PERFORMANCE	294
VII-7	FERRITE CO-PRECIPITATION PERFORMANCE.	295
VII-8	CONCENTRATION OF TOTAL CYANIDE (mg/1)	296

LIST OF TABLES (Continued)

Table		Page
VII-9	MULTIMEDIA FILTER PERFORMANCE	297
VII-10	PERFORMANCE OF SELECTED SETTLING SYSTEMS. . . .	298
VII-11	SKIMMING PERFORMANCE.	299
VII-12	COMBINED METALS DATA EFFLUENT VALUES (mg/l) . .	300
VII-13	L&S PERFORMANCE ADDITIONAL POLLUTANTS	301
VII-14	COMBINED METALS DATA SET - UNTREATED WASTEWATER.	302
VII-15	MAXIMUM POLLUTANT LEVEL IN UNTREATED WASTEWATER ADDITIONAL POLLUTANTS (mg/l)	303
VII-16	PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE PLANT A	304
VII-17	PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE PLANT B	305
VII-18	PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE PLANT C	306
VII-19	SUMMARY OF TREATMENT EFFECTIVENESS (mg/l) . . .	307
VII-20	ION EXCHANGE PERFORMANCE (All Values mg/l). . .	308
VII-21	PEAT ADSORPTION PERFORMANCE	309
VII-22	MEMBRANE FILTRATION SYSTEM EFFLUENT	310
VIII-1	COSTS OF CONTRACT HAULING[2]	365
VIII-2	EXISTING SLUDGE TREATMENT METHODS*.	366
VIII-3	MAXIMUM ENERGY REQUIREMENTS (Kwh/yr) and ESTIMATED PERCENT OF PLANT TOTAL FOR ENTIRE TREATMENT SYSTEM.	368
IX-1	STORMWATER/PRECIPITATION ALLOWANCES	390

LIST OF TABLES (Continued)

Table		Page
IX-2	MODIFICATION TO BPT PRECIPITATION EXEMPTION . .	392
IX-3	SUMMARY OF CURRENT TREATMENT PRACTICES.	393
IX-4	REGULATED POLLUTANT PARAMETERS.	394
X-1	BAT OPTIONS CONSIDERED FOR EACH OF THE NONFERROUS METALS MANUFACTURING SUBCATEGORIES .	412
X-2	MODIFICATIONS TO BAT PRECIPITATION EXEMPTION. .	413
X-3	REGULATED POLLUTANT PARAMETERS.	414
X-4	TOXIC POLLUTANTS DETECTED BUT ONLY IN TRACE AMOUNTS AND ARE NEITHER CAUSING NOR LIKELY TO CAUSE TOXIC EFFECTS	416
X-5	TOXIC POLLUTANTS EFFECTIVELY CONTROLLED BY TECHNOLOGIES UPON WHICH ARE BASED OTHER EFFLUENT LIMITATIONS AND GUIDELINES.	417
XII-1	REGULATED POLLUTANT PARAMETERS.	439
XIII-1	SUMMARY OF BCT TEST IN THE NONFERROUS METALS MANUFACTURING CATEGORY.	443

LIST OF FIGURES

Figure		Page
VII-1	FLOW DIAGRAM OF ACTIVATED CARBON ADSORPTION WITH REGENERATION	311
VII-2	ACTIVATED CARBON ADSORPTION COLUMN.	312
VII-3	COMPARATIVE SOLUBILITIES OF METAL HYDROXIDES AND SULFIDE AS A FUNCTION OF pH	313
VII-4	EFFLUENT ZINC CONCENTRATION VS. MINIMUM EFFLUENT pH	314
VII-5	LEAD SOLUBILITY IN THREE ALKALIES	315
VII-6	FILTER CONFIGURATIONS	316
VII-7	GRANULAR BED FILTRATION	317
VII-8	PRESSURE FILTRATION	318
VII-9	REPRESENTATIVE TYPES OF SEDIMENTATION	319
VII-10	GRAVITY OIL/WATER SEPARATOR	320
VII-11	HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS CADMIUM	321
VII-12	HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS CHROMIUM.	322
VII-13	HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS COPPER.	323
VII-14	HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS LEAD.	324
VII-15	HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS NICKEL AND ALUMINUM	325
VII-16	HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS ZINC.	326
VII-17	HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS IRON.	327

LIST OF FIGURES (Continued)

Figure Page

VII-18 HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS MANGANESE 328

VII-19 HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS TSS 329

VII-20 DISSOLVED AIR FLOTATION 330

VII-21 CENTRIFUGATION. 331

VII-22 TREATMENT OF CYANIDE WASTE BY ALKALINE CHLORINATION. 332

VII-23 TYPICAL OZONE PLANT FOR WASTE TREATMENT 333

VII-24 UV/OZONATION. 334

VII-25 TYPES OF EVAPORATION EQUIPMENT. 335

VII-26 GRAVITY THICKENING. 336

VII-27 ION EXCHANGE WITH REGENERATION. 337

VII-28 SIMPLIFIED REVERSE OSMOSIS SCHEMATIC. 338

VII-29 REVERSE OSMOSIS MEMBRANE CONFIGURATIONS 339

VII-30 SLUDGE DRYING BED 340

VII-31 VACUUM FILTRATION 341

VII-32 FLOW DIAGRAM FOR RECYCLING WITH A COOLING TOWER 342

VII-33 SCHEMATIC DIAGRAM OF SPINNING NOZZLE ALUMINUM REFINING PROCESS. 343

VIII-1 GEOGRAPHICALLY DISTRIBUTED CAPITAL COST FACTORS 369

VIII-2 GEOGRAPHICALLY DISTRIBUTED WAGE RATE FACTORS. . 370

VIII-3 SLUDGE HAULING COSTS 10 MILE ROUND TRIP NONHAZARDOUS WASTES 371

LIST OF FIGURES (Continued)

Figure		Page
VIII-4	COST OF SEALING GROUND AT SLAG DUMP	372
VIII-5	COST OF LINED AND UNLINED STORAGE PONDS	373
VIII-6	COST OF TRANSPORTING WASTE MATERIALS.	374
VIII-7	COST OF OIL SEPARATION.	375

SECTION I

SUMMARY

The United States Environmental Protection Agency has proposed effluent limitations and standards for the nonferrous metals manufacturing category pursuant to Sections 301, 304, 306, 307, and 501 of the Clean Water Act. The proposed regulation contains effluent limitations for best practicable control technology currently available (BPT), best conventional pollutant control technology (BCT), and best available technology economically achievable (BAT), as well as pretreatment standards for new and existing sources (PSNS and PSES), and new source performance standards (NSPS).

This Development Document highlights the technical aspects of EPA's study of the nonferrous metals manufacturing category. This volume addresses general issues pertaining to the category, while the remaining volumes contain specific subcategory reports.

The Agency's economic analysis of the regulation is set forth in a separate document entitled Economic Analysis of Effluent Guidelines - Nonferrous Metals Manufacturing Point Source Category. That document is available from the Office of Analysis and Evaluation, Economic Analysis Staff, WH-586, USEPA, Washington, D.C., 20460.

EXISTING REGULATIONS

Since 1974, implementation of the technology-based effluent limitations and standards has been guided by a series of settlement agreements into which EPA entered with several environmental groups, the latest of which occurred in 1979. NRDC v. Costle, 12 ERC 1833 (D.D.C. 1979), aff'd and remd'd, EDF v. Costle, 14 ERC 2161 (1980). Under the settlement agreements, EPA was required to develop BAT limitations and pretreatment and new source performance standards for 65 classes of pollutants discharged from specific industrial point source categories. The list of 65 classes was substantially expanded to a list of 129 specific toxic pollutants. Table I-1 presents a summary of the currently promulgated effluent limitations and standards for the nonferrous metals manufacturing point source category.

METHODOLOGY

To develop the effluent limitations and standards presented in this document, the Agency characterized the category by subdividing it, collecting raw and treated wastewater samples, and examining water usage and discharge rates, and production processes. To gather data about the category, EPA developed a questionnaire (data collection portfolio - dcp) to collect information regarding plant size, age and production, the production processes used, the quantity of process wastewater used and discharged, wastewater treatment in-place, and disposal practices. The dcp's were sent to 319 firms (416 plants) known or believed to perform nonferrous smelting and refining. These were reviewed, and it was determined that there were 314 plants among the 416 plants that were applicable to the nonferrous metals manufacturing point source category.

As a next step, EPA conducted a sampling and analytical program to characterize the raw (untreated) and treated process wastewater. This program was carried out in two stages. Screen sampling was performed at 10 facilities, each representing a major metal manufacturing process. Samples were collected from wastewater sources associated with the major manufacturing process, as well as any associated processes, including cleaning, etching, solution heat treatment, and annealing, among others. The presence or absence of the concentration of 128 of the 129 toxic pollutants, conventional and selected nonconventional pollutants in each of the samples, was determined. The toxic pollutant TCDD, number 129, was not analyzed for because an analytical standard for TCDD was judged to be too hazardous to be made generally available. A discussion of the sampling and analysis, methods, and procedures is presented in Section V.

EPA then reviewed the rate of production and wastewater generation reported in the dcp's for each manufacturing operation, as well as the wastewater characteristics determined during sampling, as the principal basis for subcategorizing the industry. The data demonstrated that the industry should be subcategorized by major metal manufacturing process. A discussion of the subcategorization scheme is presented in Section IV. For this rulemaking, the nonferrous metals manufacturing point source category has been expanded to 12 subcategories:

1. Primary Aluminum Smelting
2. Secondary Aluminum
3. Primary Copper Smelting
4. Primary Electrolytic Copper Refining
5. Secondary Copper
6. Primary Lead
7. Primary Zinc
8. Metallurgical Acid Plants
9. Primary Tungsten
10. Primary Columbium-Tantalum
11. Secondary Silver
12. Secondary Lead

The nonferrous metals manufacturing point source category is divided into subcategories based on differences in wastewater quantity and quality related to differences in industry manufacturing processes. This has resulted in the designation of 12 subcategories. Each subcategory is further subdivided into major sources of wastewater for specific limitation within the regulation. Other sources of wastewater not directly related to the production of a metal, such as maintenance and cleanup water or sanitary water, were not considered for specific limitation by the regulation. The Agency believes wastewater sources of this type are site-specific, and they are best handled on a case-by-case basis. Each wastewater source identified for this rulemaking was production-normalized. That is, each waste stream was characterized by the volume of wastewater discharged per unit of production. The sources of process wastewater identified in the nonferrous metals manufacturing category are outlined below by subcategory:

Primary Aluminum Smelting

Anode Paste Plant Wet Air Pollution Control
Anode Bake Plant Wet Air Pollution Control
Anode Contact Cooling
Cathode Manufacturing
Cathode Reprocessing
Potline Wet Air Pollution Control
Potroom Wet Air Pollution Control
Direct Chill Casting
Continuous Rod Casting
Stationary Casting
Degassing Wet Air Pollution Control

Secondary Aluminum Smelting

Scrap Drying Wet Air Pollution Control
Scrap Screening and Milling
Dross Washing
Demagging Wet Air Pollution Control
Direct Chill Casting
Stationary Casting
Shot Casting

Primary Copper Smelting

Slag Granulation
Casting Contact Cooling
Casting Wet Air Pollution Control

Primary Electrolytic Copper Refining

Anode and Cathode Rinsing
Spent Electrolyte
Casting Contact Cooling
Casting Wet Air Pollution Control
By-Product Recovery

Secondary Copper

Slag Milling and Classification
Smelting Wet Air Pollution Control
Casting Contact Cooling
Spent Electrolyte
Slag Granulation

Primary Lead

Blast Furnace Slag Granulation
Blast Furnace Wet Air Pollution Control
Zinc Fuming Wet Air Pollution Control
Dross Reverberatory Furnace Granulation
Hard Lead Refining Slag Granulation
Hard Lead Refining Wet Air Pollution Control

Primary Zinc

Zinc Reduction Furnace Wet Air Pollution Control
Leaching
Leaching Wet Air Pollution Control
Cathode and Anode Washing
Casting Wet Air Pollution Control
Casting Contact Cooling
Cadmium Plant

Metallurgical Acid Plants

Acid Plant Blowdown

Primary Tungsten

Tungstic Acid Rinse
Acid Leach Wet Air Pollution Control
Alkali Leach Wash
Ion-Exchange
Calcium Tungstate Precipitate Wash
Crystallization and Drying of Ammonium Paratungstate
Ammonium Paratungstate Conversion to Oxides Wet Air Pollution Control
Reduction to Tungsten Wet Air Pollution Control
Reduction to Tungsten Water of Formation

Primary Columbium-Tantalum

Concentrate Digestion Wet Air Pollution Control
Solvent Extraction
Solvent Extraction Wet Air Pollution Control
Precipitation and Filtration of Metal Salts
Metal Salt Drying Wet Air Pollution Control
Reduction of Salt to Metal
Reduction of Salt to Metal Wet Air Pollution Control
Consolidation and Casting Contact Cooling

Secondary Silver

Leaching
Leaching Wet Air Pollution Control
Nonphotographic Precipitation and Filtration
Nonphotographic Precipitation and Filtration Wet Air Pollution Control
Film Stripping
Film Stripping Wet Air Pollution Control
Film Stripping Precipitation and Filtration
Film Stripping Precipitation and Filtration Wet Air Pollution Control
Photographic Silver Solution Precipitation
Photographic Silver Solution Precipitation Wet Air Pollution Control
Electrolytic Refining
Furnace Wet Air Pollution Control
Casting Contact Cooling
Casting Wet Air Pollution Control

Secondary Lead

Battery Cracking
Blast and Reverberatory Wet Air Pollution Control
Kettle Wet Air Pollution Control
Casting Contact Cooling

As mentioned earlier, there are 314 plants identified in the nonferrous metals manufacturing point source category discharging an estimated 125.6 billion liters per year of process wastewater. Untreated, this process wastewater contains approximately 1,058,000 kilograms of toxic organic pollutants, 2,100,000 kilograms of toxic metal pollutants, and 60,890,000 kilograms of conventional and nonconventional pollutants.

The pollutants generated within the nonferrous metals manufacturing subcategories are diverse in nature due to varying raw materials and production processes. Thus, the Agency examined various end-of-pipe and pretreatment technologies to treat the pollutants present in the identified process wastewaters. The pollutants selected for consideration for each subcategory are presented in Section VI. The treatment technologies considered for each subcategory are shown below:

	Treatment Technologies Considered					
Subcategory	A	B	C	D	F	F
Primary Aluminum	X	X	X	X	X*	X
Secondary Aluminum	X	X	X			X
Primary Copper Electrolytic Refining	X	X	X			X
Secondary Copper	X		X			X**
Primary Zinc	X	X	X	X		X
Primary Lead	X	X	X			X
Secondary Lead	X	X	X	X		X
Primary Tungsten	X	X	X		X	X
Primary Columbium-Tantalum	X	X	X	X	X	X
Secondary Silver	X	X	X		X	X
Metallurgical Acid Plants	X	X	X			X

Note: Option A - Lime precipitation and sedimentation and cyanide precipitation, ammonia steam stripping, or oil skimming where appropriate.

Option B - Option A preceded by flow reduction by recycling variable quantities of process wastewater.

Option C - Option B plus filtration.

Option D - Option C plus activated alumina adsorption.

Option E - Option C plus activated carbon adsorption.

Option F - Option C plus reverse osmosis.

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*Option C plus activated carbon preliminary treatment of wastewater from anode bake plant wet air pollution control, anode paste plant wet air pollution control, potline wet air pollution control, potroom wet air pollution control, and cathode reprocessing.

**Option G which includes lime precipitation and sedimentation in conjunction with cooling towers and holding tanks to achieve complete recycle of process wastewater.

Engineering costs were prepared for each of the treatment options considered for each subcategory. These costs were then used by the Agency to estimate the impact of implementing the various options on the industry. For each subcategory for each control and treatment option, the number of potential closures, number of employees affected, and impact on price were estimated. These results are reported in the Economic Impact Assessement.

The Agency then reviewed each of the treatment options for each subcategory to determine the estimated mass of pollutant removed by the application of each treatment technology. The amount of removal after the application of the treatment technology is referred to as the benefit. The methodology used to calculate the pollutant reduction benefits is presented in Section X.

TECHNOLOGY BASIS FOR LIMITATIONS AND STANDARDS

After examining the various treatment technologies, the Agency has identified BPT to represent the average of the best existing technology. Metals removal based on lime precipitation and sedimentation technology is the basis for the BPT limitations for 10 subcategories. The other two subcategories, primary copper smelting and secondary copper, are already subject to zero discharge of all process wastewater pollutants. Steam stripping is selected as the basis for ammonia limitations in four subcategories. To meet the newly-proposed BPT effluent limitations based on this technology, it is estimated that the nonferrous metals manufacturing point source category will incur a capital cost of \$3.34 million (1978 dollars) and an annual cost of \$2.31 million (1978 dollars).

One goal of BAT is to achieve increased levels of toxic pollutant removal. For BAT, the Agency has built upon the BPT technology basis by adding in-process control technologies which include recycle of process water from air pollution control and metal contact cooling waste streams, as well as other flow reductions, where achievable. Filtration is added as an effluent polishing step to the end-of-pipe treatment scheme. In addition, carbon adsorption and cyanide precipitation are proposed for the primary aluminum BAT treatment scheme. These two technologies are transferred to the primary aluminum subcategory because existing treatment within the subcategory does not effectively remove toxic organic pollutants and cyanide.

To meet the BAT effluent limitations based on this technology, the nonferrous metals manufacturing point source category is estimated to incur a capital cost of \$44.91 million (1978 dollars) and an annual cost of \$25.36 million (1978 dollars).

Due to current adverse structural economic changes that are not fully reflected in the Agency's current economic analysis, alternative BAT effluent limitations also are proposed for the primary electrolytic copper refining, secondary silver, and secondary lead subcategories. The alternative technology scheme upon which the BAT limitations are based is lime precipitation and sedimentation with in-process control technologies which include recycle of process water from air pollution control and metal contact cooling waste streams. To meet the BAT effluent limitations based on the alternative technology, the estimated capital cost is $42.48 million (1978 dollars) and the annual cost is $23.93 million (1978 dollars).

BDT, which is the technical basis of NSPS, is equivalent to BAT with the exception of primary aluminum and primary lead. In selecting BDT, EPA recognizes that new plants have the opportunity to implement the best and most efficient manufacturing processes and treatment technology. As such, new source performance standards for the primary aluminum subcategory are based on dry alumina air pollution scrubbing systems or 100 percent recycle. Implementation of this technology eliminates the discharge of toxic organics due to air emission scrubbing associated with anode paste plants, anode bake plants, potlines and potrooms, as well as from cathode reprocessing operations. New source performance standards for the primary lead subcategory require zero discharge of all process wastewaters. Zero discharge is achievable through dry slag conditioning instead of using high pressure water jets to granulate smelter slag. Table II-3 presents a summary, for each subcategory and each waste stream within that subcategory, of the discharge flow allowances, the option selected, and the proposed NSPS.

For PSES, the Agency selected the same technology as BAT, which is BPT end-of-pipe treatment in conjunction with several in-process flow reduction control techniques followed by filtration as an effluent polishing step. For PSNS, the Agency selected end-of-pipe treatment and in-process flow reduction control techniques equivalent to NSPS. To meet the pretreatment standards for existing sources, the nonferrous metals manufacturing point source category is estimated to incur a capital cost of $9.78 million (1978 dollars) and an annual cost of $6.73 million (1978 dollars).

Due to current adverse structural economic changes that are not fully reflected in the Agency's current economic analysis, alternative PSES also are proposed for the secondary silver and secondary lead subcategories. The alternative technology scheme upon which the PSES are based is lime precipitation and sedimentation with in-process control technologies which include recycle of process water from air pollution control and metal contact cooling waste streams. To meet the PSES based on the alternate technology, the estimated capital cost is $8.12 million (1978 dollars) and the annual cost is $5.24 million (1978 dollars). Tables II-2 and II-3 present a summary, for each subcategory and for each waste stream within that subcategory, of the discharge flow allowances, the option selected, and the proposed PSES and PSNS.

Table I-1

CURRENTLY PROMULGATED LIMITATIONS AND STANDARDS - NONFERROUS METALS MANUFACTURING

Subcategory	BPT	BAT	NSPS	PSES	PSNS
Primary Aluminum	LS	LS,FR	LS,FR[1]	--	LS,FR[1]
Secondary Aluminum	LS, PH	ND	LS,FR	OS,pH,AS	LS,FR
Primary Copper Smelting	ND[2]	ND[2,3]	--	--	--
Primary Electrolytic Copper Refining	LS	LS,FR[2,3,4]	--	--	--
Secondary Copper	ND[2,3]	ND[2,3]	--	LS	--
Primary Lead	ND[2,3]	ND[2,3]	--	--	--
Primary Zinc	LS	LS,FR	--	--	--
Metallurgical Acid Plants[4]	LS	--	--	--	--
Primary Tungsten	--	--	--	--	--
Primary Columbium-Tantalum	--	--	--	--	--
Secondary Silver	--	--	--	--	--
Secondary Lead	--	--	--	--	--

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[1] Includes additional flow reduction beyond BAT.

[2] Allows a discharge without limitation during a 10-year, 24-hour rainfall (or 25-year, 24-hour rainfalls at BAT) for stormwater falling on the wastewater cooling or settling pond.

[3] Allows a discharge, subject to concentration limitations, for a flow equal to the net monthly precipitation on the wastewater settling pond.

[4] Copper acid plants only; zinc and lead acid plants are currently covered in the primary zinc and primary lead subcategories.

LS - lime precipitation and sedimentation.
FR - flow reduction.
ND - no discharge.
OS - oil skimming.
pH - pH adjustment.
AS - ammonia air stripping.

SECTION II

CONCLUSIONS

EPA has divided the nonferrous metals manufacturing point source category into 12 subcategories for the purpose of developing effluent limitations and standards. This section presents the proposed effluent limitations and standards developed for 10 of the 12 subcategories according to the following format:

	Table Number			
Subcategory	BPT Effluent Limitations	BAT and PSES Effluent Limitations	NSPS and PSNS Effluent Limitations	BCT Effluent Limitations
Primary Aluminum	-	6	16	26
Secondary Aluminum	-	7	17	27
Primary Electrolytic Copper Refining	-	8	18	28
Primary Lead	1	9	19	29
Primary Zinc	-	10	20	30
Metallurgical Acid Plants	-	11	21	31
Primary Tungsten	2	12	22	32
Primary Columbium-Tantalum	3	13	23	33
Secondary Silver	4	14	24	34
Secondary Lead	5	15	25	35

The other two subcategories, primary copper smelting and secondary copper, are proposed as zero discharge for all process wastewater pollutants.

Table II-1

PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BPT EFFLUENT LIMITATIONS (mg/kkg)		
		Pb	Zn	TSS
PRIMARY LEAD				
Blast Furnace Slag Granulation	3,730			
Monthly Average		484.9	2,088.8	74,600.0
Maximum		559.5	4,960.9	152,930.0
Blast Furnace Wet Air Pollution Control	0			
Monthly Average		0	0	0
Maximum		0	0	0
Zinc Fuming Furnace Wet Air Pollution Control	426			
Monthly Average		55.38	238.56	8,520.0
Maximum		63.9	566.58	17,466.0
Dross Reverberatory Furnace Wet Air Pollution Control	0			
Monthly Average		0	0	0
Maximum		0	0	0
Dross Reverberatory Furnace Granulation	3,134			
Monthly Average		407.42	1,755.04	62,680.0
Maximum		470.10	4,168.22	128,494.0
Hard Lead Refining Wet Air Pollution Control	19,836			
Monthly Average		2,578.68	11,108.16	396,720.0
Maximum		2,975.40	26,381.88	813,276.0
Hard Lead Refining Slag	0			
Monthly Average		0	0	0
Maximum		0	0	0

Table II-2

PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BPT EFFLUENT LIMITATIONS (mg/kkg) Pb	Se	Zn	Ammonia	TSS
PRIMARY TUNGSTEN						
Tungsten Acid Rinse	47,600					
Monthly Average		6,188.0	26,180.0	26,656.0	2,789,360.0	952,000.0
Maximum		7,140.0	58,548.0	63,308.0	6,330,800.0	1,951,600.0
Acid Leach Wet Air Pollution Control	37,700					
Monthly Average		4,901.0	20,735.0	21,112.0	2,209,220.0	754,000.0
Maximum		5,655.0	46,371.0	50,141.0	5,014,100.0	1,545,700.0
Alkali Leach Wash	46,700					
Monthly Average		6,071.0	25,685.0	26,152.0	2,736,620.0	934,000.0
Maximum		7,055.0	57,441.0	62,111.0	6,211,100.0	1,914,700.0
Ion-Exchange Raffinate	51,200					
Monthly Average		6,656.0	28,160.0	28,672.0	3,000,320.0	1,024,000.0
Maximum		7,680.0	62,976.0	68,096.0	6,809,600.0	2,099,200.0
Calcium Tungstate Precipitate Wash	37,200					
Monthly Average		4,836.0	20,460.0	20,832.0	2,179,920.0	744,000.0
Maximum		5,580.0	45,756.0	49,476.0	4,947,600.0	1,525,200.0
Crystallization and Drying of Ammonium Paratungstate	0					
Monthly Average		0	0	0	0	0
Maximum		0	0	0	0	0

Table II-2 (Continued)

PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BPT EFFLUENT LIMITATIONS (mg/kkg)				
		Pb	Se	Zn	Ammonia	TSS
PRIMARY TUNGSTEN (Cont.)						
Ammonium Paratungstate Conversion to Oxides Wet Air Pollution Control	29,900					
Monthly Average		2,717.0	11,495.0	11,704.0	1,224,740.0	418,000.0
Maximum		3,135.0	25,707.0	27,797.0	2,779,700.0	856,900.0
Reduction to Tungsten Wet Air Pollution Control	73,200					
Monthly Average		9,516.0	40,260.0	40,992.0	4,289,520.0	1,464,000.0
Maximum		10,980.0	90,036.0	97,356.0	9,735,600.0	3,002,200.0
Reduction to Tungsten Water of Formation	19,400					
Monthly Average		2,522.0	10,670.0	10,864.0	1,136,840.0	388,000.0
Maximum		2,910.0	23,862.0	25,802.0	2,580,200.0	795,400.0

Table II-3

PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BPT EFFLUENT LIMITATIONS (mg/kkg) Pb	Zn	Fl	Ammonia	TSS
PRIMARY COLUMBIUM-TANTALUM						
Concentrate Digestion Wet Air Pollution Control	10,915					
Monthly Average		1,418.95	6,112.40	288,156.0	639,619.0	218,300.0
Maximum		1,637.25	14,516.95	649,442.50	1,451,695.0	447,515.0
Solvent Extraction Raffinate	26,916					
Monthly Average		3,499.08	15,072.96	710,582.40	1,577,277.60	538,320.0
Maximum		4,037.40	35,798.28	1,601,502.0	3,579,828.0	1,103,556.0
Solvent Extraction Wet Air Pollution Control	4,301					
Monthly Average		559.18	2,408.78	113,556.96	252,062.04	86,028.0
Maximum		645.21	5,720.86	255,933.30	572,086.20	176,357.40
Precipitation and Filtration of Metal Salts	247,223					
Monthly Average		32,138.99	138,444.88	6,526,687.20	14,487,267.80	4,944,460.0
Maximum		37,083.45	328,806.59	14,709,768.50	32,880,659.0	10,136,143.0
Metal Salt Drying Wet Air Pollution Control	83,643					
Monthly Average		10,873.59	46,840.08	2,208,175.20	4,901,479.80	1,672,860.0
Maximum		12,546.45	111,245.19	4,976,758.50	11,124,519.0	3,429,363.0

Table II-3 (Continued)

PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BPT EFFLUENT LIMITATIONS (mg/kkg)				
		Pb	Zn	Fl	Ammonia	TSS
PRIMARY COLUMBIUM-TANTALUM (Cont.)						
Reduction of Salt to Metal	352,663					
Monthly Average		45,846.19	197,491.28	9,310,303.20	20,666,051.80	7,053,260.0
Maximum		52,899.45	469,041.79	20,983,448.50	46,904,179.0	14,459,183.0
Reduction of Salt to Metal Wet Air Pollution Control	21,521					
Monthly Average		2,797.73	12,051.76	568,154.40	1,261,130.60	430,420.0
Maximum		3,228.15	28,622.93	1,280,499.50	2,862,293.0	882,361.0
Consolidation and Casting Contact Cooling	0					
Monthly Average		0	0	0	0	0
Maximum		0	0	0	0	0

Table II-4

PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BPT EFFLUENT LIMITATIONS (mg/kkg)			
		Cu	Zn	Ammonia	TSS
SECONDARY SILVER					
Film Stripping	1,619,000				
Monthly Average		1,619,000.00	906,640.0	94,873,400.0	32,380,000.0
Maximum		3,076,100.0	2,153,270.0	215,327,000.0	66,379,000.0
Film Stripping Wet Air Pollution Control	15,580				
Monthly Average		15,580.0	8,724.80	912,988.0	311,600.0
Maximum		29,602.0	20,721.40	2,072,140.0	638,780.0
Precipitation and Filtration of Film Stripping Solutions	1,851,000				
Monthly Average		1,851,000.0	1,036,560.0	108,468,600.0	37,020,000.0
Maximum		3,516,900.0	2,461,830.0	246,183,000.0	75,891,000.0
Precipitation and Filtration of Film Stripping Solutions Wet Air Pollution Control	15,580				
Monthly Average		15,580.0	8,742.80	912,988.0	311,600.0
Maximum		29,602.0	20,721.40	2,072,140.0	638,780.0
Precipitation and Filtration of Photographic Solutions	854,000				
Monthly Average		854,000.0	478,240.0	50,044,400.0	17,080,000.0
Maximum		1,622,600.0	1,135,820.0	113,582,000.0	35,014,000.0
Precipitation and Filtration of Photographic Solutions Wet Air Pollution Control	390,300				
Monthly Average		390,300.0	218,568.0	22,871,580.0	7,806,000.0
Maximum		741,570.0	519,099.0	51,909,900.0	16,002,300.0

Table II-4 (Continued)

PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BPT EFFLUENT LIMITATIONS (mg/kkg)			
		Cu	Zn	Ammonia	TSS
SECONDARY SILVER (Cont.)					
Electrolytic Refining	24,316				
Monthly Average		24,316.0	13,616.96	1,424,917.60	486,320.0
Maximum		46,200.40	32,340.28	3,234,028.0	996,956.0
Furnace Wet Air Pollution Control	21,519				
Monthly Average		21,519.0	12,050.64	1,261,013.40	430,380.0
Maximum		40,886.10	28,620.27	2,862,027.0	882,279.0
Casting Contact Cooling	12,035				
Monthly Average		12,035.0	6,739.60	705,251.0	240,700.0
Maximum		22,866.50	16,006.55	1,600,655.0	493,435.0
Casting Wet Air Pollution Control	4,741				
Monthly Average		4,741.0	2,654.96	277,822.60	94,820.0
Maximum		9,007.90	6,305.53	630,553.0	194,381.0
Leaching	2,780				
Monthly Average		2,780.0	1,556.8	162,908.0	55,600.0
Maximum		5,282.0	3,697.4	369,740.0	113,980.0
Leaching Wet Air Pollution Control	142,389				
Monthly Average		142,389.0	79,737.84	8,343,995.40	2,847,780.0
Maximum		270,539.10	189,377.37	18,937,737.0	5,837,949.0

Table II-4 (Continued)

PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BPT EFFLUENT LIMITATIONS (mg/kkg)			
		Cu	Zn	Ammonia	TSS
SECONDARY SILVER (Cont.)					
Precipitation and Filtration of Non-photographic Solutions	98,577				
Monthly Average		98,577.0	55,203.12	5,776,612.20	1,971,540.0
Maximum		187,296.30	131,107.41	13,110,741.0	4,041,657.0
Precipitation and Filtration of Non-photographic Solutions Wet Air Pollution Control	79,931				
Monthly Average		79,931.0	44,761.36	4,683,956.60	1,598,620.0
Maximum		151,868.90	106,308.23	10,630,823.0	3,277,171.0

Table II-5

PROPOSED BPT EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BPT EFFLUENT LIMITATIONS (mg/kkg)					
		Sb	As	Pb	Zn	Ammonia	TSS
SECONDARY LEAD							
Battery Cracking	940						
Monthly Average		1,193.80	808.40	122.20	526.40	0.0	18,800.0
Maximum		2,697.80	1,964.60	141.0	1,250.20	0.0	38,540.0
Blast and Reverberatory Furnace Wet Air Pollution Control	3,380						
Monthly Average		4,292.60	2,906.80	439.40	1,892.80	0.0	67,600.0
Maximum		9,700.60	7,064.20	507.0	4,495.40	0.0	138,580.0
Kettle Wet Air Pollution Control	0						
Monthly Average		0	0	0	0	0	0
Maximum		0	0	0	0	0	0
Casting Contact Cooling	221.2						
Monthly Average		280.92	190.23	28.76	123.87	0.0	4,424.0
Maximum		634.84	462.31	33.18	294.20	0.0	9,069.20

Table II-6

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	Benzo-(a) pyrene	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)				
			Sb	CN	Ni	Al	Fl
PRIMARY ALUMINUM							
Anode Paste Plant Wet Air Pollution Control	103						
Monthly Average		-	88.58	8.24	38.11	127.72	1,812.80
Maximum		1.03	198.79	20.60	56.65	312.09	4,089.10
Anode Bake Plant Wet Air Pollution Control	49.4						
Monthly Average		-	42.48	3.95	18.28	61.26	869.44
Maximum		0.49	95.34	9.88	27.17	149.68	1,961.18
Cathode Manufacturing	77.4						
Monthly Average			66.56	6.19	28.64	95.98	1,362.24
Maximum			149.38	15.48	42.57	234.52	3,072.78
Cathode Reprocessing	952						
Monthly Average		-	818.72	76.16	352.24	1,180.48	16,755.20
Maximum		9.52	1,837.36	190.40	523.60	2,884.56	37,794.40
Anode Contact Cooling	621						
Monthly Average			534.15	49.69	229.81	770.16	10,931.36
Maximum			1,198.72	124.22	341.61	1,881.93	24,657.67
Potline Wet Air Pollution Control	838						
Monthly Average		-	720.68	67.04	310.06	1,039.12	14,748.80
Maximum		8.38	1,617.34	167.60	460.90	2,539.14	33,268.60
Potroom Wet Air Pollution Control	1,305						
Monthly Average		-	1,122.30	104.40	482.85	1,618.20	22,968.0
Maximum		13.05	2,518.65	261.0	717.75	3,954.15	51,808.5

Table II-6 (Continued)

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	Benzo-(a) pyrene	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg) Sb	CN	Ni	Al	Fl
PRIMARY ALUMINUM (Cont.)							
Degassing Wet Air Pollution Control	0						
Monthly Average			0	0	0	0	0
Maximum			0	0	0	0	0
Direct Chill Casting Contact Cooling	1,999						
Monthly Average			1,719.14	159.92	739.63	2,478.76	35,182.40
Maximum			3,858.07	399.80	1,099.45	6,056.97	79,360.30
Continuous Rod Casting Contact Cooling	104						
Monthly Average			89.69	8.34	38.59	129.33	1,835.68
Maximum			201.29	20.86	57.37	316.03	4,140.71
Stationary Casting Contact Cooling	0						
Monthly Average			0	0	0	0	0
Maximum			0	0	0	0	0

Table II-7

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg) Pb	Zn	Al	Ammonia
SECONDARY ALUMINUM					
Scrap Drying Wet Air Pollution Control	0				
Monthly Average		0	0	0	0
Maximum		0	0	0	0
Scrap Screening and Milling	0				
Monthly Average		0	0	0	0
Maximum		0	0	0	0
Dross Washing	10,868				
Monthly Average		978.12	4,564.56	13,476.32	636,864.80
Maximum		1,086.80	11,085.36	32,930.04	1,445,444.0
Demagging Wet Air Pollution Control	800				
Monthly Average		72.0	336.0	992.0	46,880.0
Maximum		80.0	816.0	2,424.0	106,400.0
Direct Chill Casting Contact Cooling	1,999				
Monthly Average		179.91	839.58	2,478.76	117,141.40
Maximum		199.90	2,038.98	6,056.97	265.867.0
Stationary Casting Contact Cooling	0				
Monthly Average		0	0	0	0
Maximum		0	0	0	0
Shot Casting Contact Cooling	0				
Monthly Average		0	0	0	0
Maximum		0	0	0	0

Table II-8

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)		
		Cu	Pb	Ni
PRIMARY ELECTROLYTIC COPPER REFINING				
Anode and Cathode Rinsing	0			
Alternative A				
Monthly Average		0	0	0
Maximum		0	0	0
Alternative B				
Monthly Average		0	0	0
Maximum		0	0	0
Spent Electrolyte	0			
Alternative A				
Monthly Average		0	0	0
Maximum		0	0	0
Alternative B				
Monthly Average		0	0	0
Maximum		0	0	0
Casting Contact Cooling	498			
Alternative A				
Monthly Average		498.0	64.74	498.0
Maximum		946.20	74.70	702.18

Table II-8 (Continued)

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)		
		Cu	Pb	Ni
PRIMARY ELECTROLYTIC COPPER REFINING (Cont.)				
Alternative B				
Monthly Average		303.78	44.82	184.26
Maximum		637.44	49.80	273.90
Casting Wet Air Pollution Control	0			
Alternative A				
Monthly Average		0	0	0
Maximum		0	0	0
Alternative B				
Monthly Average		0	0	0
Maximum		0	0	0
By-Product Recovery	0			
Alternative A				
Monthly Average		0	0	0
Maximum		0	0	0
Alternative B				
Monthly Average		0	0	0
Maximum		0	0	0

Table II-9

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)	
		Pb	Zn
PRIMARY LEAD			
Blast Furnace Slag Granulation	3,730		
Monthly Average		335.7	1,566.6
Maximum		373.0	3,804.6
Blast Furnace Wet Air Pollution Control	0		
Monthly Average		0	0
Maximum		0	0
Zinc Fuming Furnace Wet Air Pollution Control	0		
Monthly Average		0	0
Maximum		0	0
Dross Reverberatory Wet Air Pollution Control	0		
Monthly Average		0	0
Maximum		0	0
Dross Reverberatory Furnace Granulation	0		
Monthly Average		0	0
Maximum		0	0
Hard Lead Refining Wet Air Pollution Control	0		
Monthly Average		0	0
Maximum		0	0
Hard Lead Refining Slag Granulation	0		
Monthly Average		0	0
Maximum		0	0

Table II-10

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)			
		Cd	Cu	Pb	Zn
PRIMARY ZINC					
Zinc Reduction Furnace Wet Air Pollution Control	1,668				
Monthly Average		133.46	1,017.66	150.15	700.69
Maximum		333.66	2,135.42	166.83	1,701.67
Leaching	1,310				
Monthly Average		104.80	799.10	117.90	550.20
Maximum		262.0	1,676.80	131.0	1,336.20
Leaching Wet Air Pollution Control	0				
Monthly Average		0	0	0	0
Maximum		0	0	0	0
Cathode and Anode Washing	19,850				
Monthly Average		1,588.0	12,108.50	1,786.50	8,337.0
Maximum		3,970.0	25,408.0	1,985.0	20,247.0
Casting Wet Air Pollution Control	257				
Monthly Average		20.56	156.77	23.13	107.94
Maximum		51.40	328.96	25.70	262.14
Casting Contact Cooling	181				
Monthly Average		14.48	110.41	16.29	76.02
Maximum		36.20	231.68	18.10	184.62
Cadmium Plant	6,171				
Monthly Average		493.68	3,764.31	555.39	2,591.82
Maximum		1,234.20	7,898.88	617.10	6,294.42

Table II-11

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)				
		As	Cd	Cu	Pb	Zn
METALLURGICAL ACID PLANTS						
Acid Plant Blowdown	2,554					
Monthly Average		1,455.78	204.32	1,557.94	229.86	1,072.68
Maximum		3,550.06	510.80	3,269.12	255.40	2,605.08

Table II-12

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg) Pb	Se	Zn	Ammonia
PRIMARY TUNGSTEN					
Tungsten Acid Rinse	47,600				
Monthly Average		4,284.0	17,612.0	19,992.0	2,789,360.0
Maximum		4,760.0	39,032.0	48,552.0	6,330,800.0
Acid Leach Wet Air Pollution Control	3,770				
Monthly Average		339.30	1,394.90	1,583.40	220,922.0
Maximum		377.0	3,091.40	3,845.40	501,410.0
Alkali Leach Wash	46,700				
Monthly Average		4,203.0	17,279.0	19,614.0	2,736,620.0
Maximum		4,670.0	38,294.0	47,634.0	6,211,100.0
Ion-Exchange Raffinate	51,200				
Monthly Average		4,608.0	41,984.0	21,504.0	3,000,320.0
Maximum		5,120.0	18,944.0	52,224.0	6,809,600.0
Calcium Tungstate Precipitate	37,299				
Monthly Average		3,348.0	13,764.0	15,624.0	2,179,920.0
Maximum		3,720.0	30,504.0	37,944.0	4,947,600.0
Crystallization and Drying of Ammonium Paratungstate	0				
Monthly Average		0	0	0	0
Maximum		0	0	0	0

Table II-12 (Continued)

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)			
		Pb	Se	Zn	Ammonia
PRIMARY TUNGSTEN (Cont.)					
Ammonium Paratungstate Conversion to Oxides Wet Air Pollution Control	20,900				
Monthly Average		2,717.0	7,733.0	11,704.0	1,224,740.0
Maximum		3,135.0	17,138.0	27,797.0	2,779,700.0
Reduction to Tungsten Wet Air Pollution Control	7,320				
Monthly Average		658.80	482.85	3,074.40	428,952.0
Maximum		732.0	1,070.10	7,466.40	973,560.0
Reduction to Tungsten Water of Formation	19,400				
Monthly Average		1,746.0	7,178.0	8,148.0	1,136,840.0
Maximum		1,940.0	15,908.0	19,788.0	2,580,200.0

Table II-13

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)			
		Pb	Zn	Fl	Ammonia
PRIMARY COLUMBIUM-TANTALUM					
Concentrate Digestion Wet Air Pollution Control	5,156				
Monthly Average		464.07	2,165.65	90,750.88	302,159.18
Maximum		515.63	5,259.43	204,705.11	685,787.90
Solvent Extraction Raffinate	26,916				
Monthly Average		2,422.44	11,304.72	473,721.60	1,577,277.60
Maximum		2,691.60	27,454.32	1,068,565.20	3,579,828.0
Solvent Extraction Wet Air Pollution Control	430				
Monthly Average		38.71	180.64	7,569.76	25,203.86
Maximum		43.01	438.70	17,074.97	57,203.30
Precipitation and Filtration of Metal Salts	247,223				
Monthly Average		22,250.07	103,833.66	4,351,124.80	14,487,267.80
Maximum		24,722.30	252,167.46	9,814,753.10	32,880,659.0
Metal Salt Drying Wet Air Pollution Control	16,479				
Monthly Average		1,483.11	6,921.18	290,030.40	965,669.40
Maximum		1,647.90	16,808.58	654,216.30	2,191,707.0

Table II-13 (Continued)

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg) Pb	Zn	Fl	Ammonia
PRIMARY COLUMBIUM-TANTALUM (Cont.)					
Reduction of Salt to Metal	352,663				
Monthly Average		31,739.67	148,118.46	6,206,868.80	20,666,051.80
Maximum		35,266.30	359,716.26	14,000,721.10	46,904,179.0
Reduction of Salt to Metal Wet Air Pollution Control	21,521				
Monthly Average		1,936.89	9,038.82	378,769.60	1,261,130.60
Maximum		2,152.10	21,951.42	854,383.70	2,862,293.0
Consolidation and Casting	0				
Monthly Average		0	0	0	0
Maximum		0	0	0	0

Table II-14

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)		
		Cu	Zn	Ammonia
SECONDARY SILVER				
Film Stripping	1,619,000			
Alternative A				
Monthly Average		1,619,000.0	906,640.0	94,873,400.0
Maximum		3,076,100.0	2,153,270.0	215,327,000.0
Alternative B				
Monthly Average		987,590.0	679,980.0	94,873,400.0
Maximum		2,072,320.0	1,651,380.0	215,327,000.0
Film Stripping Wet Air Pollution Control	15,580			
Alternative A				
Monthly Average		15,580.0	8,724.8	912,988.0
Maximum		29,602.0	20,721.0	2,072,140.0
Alternative B				
Monthly Average		9,503.80	6,543.60	912,988.0
Maximum		19,942.40	15,891.60	2,072,140.0
Precipitation and Filtration of Film Stripping Solutions	1,851,000			
Alternative A				
Monthly Average		1,851,000.0	1,036,560.0	108,468,600.0
Maximum		3,516,900.0	2,461,830.0	246,183,000.0

Table II-14 (Continued)

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)		
		Cu	Zn	Ammonia
SECONDARY SILVER (Cont.)				
Alternative B				
Monthly Average		1,129,110.0	777,420.0	108,468,600.0
Maximum		2,369,280.0	1,888,020.0	246,183,000.0
Precipitation and Filtration of Film Stripping Solutions Wet Air Pollution Control	15,580			
Alternative A				
Monthly Average		15,580.0	8,724.8	912,988.0
Maximum		29,602.0	20,721.0	2,072,140.0
Alternative B				
Monthly Average		9,503.80	6,543.60	912,988.0
Maximum		19,942.40	15,891.60	2,072,140.0
Precipitation and Filtration of Photographic Solutions	854,000			
Alternative A				
Monthly Average		854,000.0	478,240.0	50,044,400.0
Maximum		1,622,600.0	1,135,820.0	113,582,000.0
Alternative B				
Monthly Average		520,940.0	358,680.0	50,044,400.0
Maximum		1,093,120.0	871,080.0	113,582,000.0

Table II-14 (Continued)

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)		
		Cu	Zn	Ammonia
SECONDARY SILVER (Cont.)				
Precipitation and Filtration of Photographic Solutions Wet Air Pollution Control	390,300			
Alternative A				
Monthly Average		390,300.0	218,568.0	22,871,580.0
Maximum		741,570.0	519,099.0	51,909,900.0
Alternative B				
Monthly Average		238,083.0	163,926.0	22,871,580.0
Maximum		499,584.0	398,106.0	51,909,900.0
Electrolytic Refining	24,316			
Alternative A				
Monthly Average		24,316.0	13,616.96	1,424,917.60
Maximum		46,200.4	32,340.28	3,234,028.0
Alternative B				
Monthly Average		14,832.76	10,212.72	1,424,917.60
Maximum		31,124.48	24,802.82	3,234,028.0

Table II-14 (Continued)

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)		
		Cu	Zn	Ammonia
SECONDARY SILVER (Cont.)				
Furnace Wet Air Pollution Control	0			
Alternative A				
Monthly Average		0	0	0
Maximum		0	0	0
Alternative B				
Monthly Average		0	0	0
Maximum		0	0	0
Casting Contact Cooling	1,204			
Alternative A				
Monthly Average		1,204.0	674.24	70,554.40
Maximum		2,287.6	1,601.32	160,132.0
Alternative B				
Monthly Average		734.44	505.68	70,554.40
Maximum		1,541.12	1,228.08	160,132.0
Casting Wet Air Pollution Control	4,741			
Alternative A				
Monthly Average		4,741.0	2,654.96	277,822.60
Maximum		9,007.8	6,305.53	630,553.0
Alternative B				
Monthly Average		2,892.01	1,991.22	277,822.60
Maximum		6,068.48	4,835.82	630,553.0

Table II-14 (Continued)

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)		
		Cu	Zn	Ammonia
SECONDARY SILVER (Cont.)				
Leaching	2,780			
Alternative A				
Monthly Average		2,780.0	1,566.8	165,662.20
Maximum		5,282.0	3,697.4	369,740.0
Alternative B				
Monthly Average		1,695.8	1,167.6	162,908.0
Maximum		3,558.4	2,835.6	369,740.0
Leaching Wet Air Pollution Control	142,389			
Alternative A				
Monthly Average		142,389.0	79,737.84	8,343,995.40
Maximum		270,539.1	189,377.37	18,937,737.0
Alternative B				
Monthly Average		86,857.29	59,803.38	8,343,995.40
Maximum		182,257.92	145,236.78	18,937,737.0
Precipitation and Filtration of Nonphotographic Solutions	98,577			
Alternative A				
Monthly Average		98,577.0	55,203.12	5,776,612.20
Maximum		187,296.30	131,107.41	13,110,741.0
Alternative B				
Monthly Average		60,131.97	41,402.34	5,776,612.20
Maximum		126,178.56	100,548.54	13,110,741.0

Table II-14 (Continued)

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)		
		Cu	Zn	Ammonia
SECONDARY SILVER (Cont.)				
Precipitation and Filtration of Nonphotographic Solutions Wet Air Pollution Control	79,931			
Alternative A				
Monthly Average		79,931.0	44,761.36	4,683,956.60
Maximum		151,868.9	106,308.23	10,630,823.0
Alternative B				
Monthly Average		48,757.91	33,571.02	4,683,956.60
Maximum		102,311.68	81,529.62	10,630,823.0

Table II-15

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg) Sb	As	Pb	Zn	Ammonia
SECONDARY LEAD						
Battery Cracking	673					
Alternative A						
Monthly Average		854.71	578.78	87.49	376.88	0.0
Maximum		1,931.51	1,406.57	100.95	895.09	0.0
Alternative B						
Monthly Average		578.78	383.61	60.57	282.66	0.0
Maximum		1,298.89	935.47	67.30	686.46	0.0
Blast and Reverberatory Furnace Wet Air Pollution Control	2,610					
Alternative A						
Monthly Average		3,314.7	2,244.6	339.3	1,461.6	0.0
Maximum		7,490.7	5,454.9	391.5	3,471.30	0.0
Alternative B						
Monthly Average		2,244.60	1,487.70	234.90	1,096.20	0.0
Maximum		5,037.30	3,627.90	261.0	2,662.20	0.0
Kettle Wet Air Pollution Control	0					
Alternative A						
Monthly Average		0	0	0	0	0
Maximum		0	0	0	0	0
Alternative B						
Monthly Average		0	0	0	0	0
Maximum		0	0	0	0	0

Table II-15 (Continued)

PROPOSED BAT/PSES EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)				
		Sb	As	Pb	Zn	Ammonia
SECONDARY LEAD (Cont.)						
Casting Contact Cooling	22.1					
Alternative A						
Monthly Average		28.07	19.01	2.87	12.38	0.0
Maximum		63.43	46.19	3.32	29.39	0.0
Alternative B						
Monthly Average		19.006	12.60	1.99	9.28	0.0
Maximum		42.653	30.72	2.21	22.54	0.0

Table II-16

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	Benzo-(a) pyrene	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)						
			Sb	CN	Ni	Al	Fl	O&G*	TSS*
PRIMARY ALUMINUM									
Anode Paste Plant Wet Air Pollution Control	0								
Monthly Average		-	0	0	0	0	0	0	0
Maximum		0	0	0	0	0	0	0	0
Anode Bake Plant Wet Air Pollution Control	0								
Monthly Average		-	0	0	0	0	0	0	0
Maximum		0	0	0	0	0	0	0	0
Cathode Manufacturing	77.4								
Monthly Average			66.56	6.19	28.64	95.98	1,362.24	774.0	928.80
Maximum			149.38	15.48	42.57	234.52	3,072.78	774.0	1,610.0
Cathode Reprocessing	952								
Monthly Average		-	818.72	76.16	352.24	1,180.48	16,755.20	9,520.0	11,424.0
Maximum		9.52	1,837.36	190.40	523.60	2,884.56	37,794.40	9,520.0	14,280.0
Anode Contact Cooling	621								
Monthly Average			534.15	49.69	229.81	770.16	10,931.36	6,211.0	7,453.20
Maximum			1,198.72	124.22	341.61	1,881.93	24,657.67	6,211.0	9,316.50
Potline Wet Air Pollution Control	0								
Monthly Average		-	0	0	0	0	0	0	0
Maximum		0	0	0	0	0	0	0	0

Table II-16 (Continued)

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	Benzo-(a) pyrene	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)						
			Sb	CN	Ni	Al	Fl	O&G*	TSS*
PRIMARY ALUMINUM (Cont.)									
Potroom Wet Air Pollution Control	0								
Monthly Average		-	0	0	0	0	0	0	0
Maximum		0	0	0	0	0	0	0	0
Degassing Wet Air Pollution Control	0								
Monthly Average			0	0	0	0	0	0	0
Maximum			0	0	0	0	0	0	0
Direct Chill Casting Contact Cooling	1,999								
Monthly Average			1,719.14	159.92	739.63	2,478.76	35,182.40	19,990.0	23,988.0
Maximum			3,858.07	399.80	1,099.45	6,056.97	79,360.30	19,990.0	29,985.0
Continuous Rod Casting Contact Cooling	104								
Monthly Average			89.69	8.34	38.59	129.33	1,835.68	1,043.0	1,251.60
Maximum			201.29	20.86	57.37	316.03	4,140.71	1,043.0	1,564.50
Stationary Casting Contact Cooling	0								
Monthly Average			0	0	0	0	0	0	0
Maximum			0	0	0	0	0	0	0

*Conventional pollutants are controlled by NSPS only.

Table II-17

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)					
		Pb	Zn	Al	Ammonia	O&G*	TSS*
SECONDARY ALUMINUM							
Scrap Drying Wet Air Pollution Control	0						
Monthly Average		0	0	0	0	0	0
Maximum		0	0	0	0	0	0
Scrap Screening and Milling	0						
Monthly Average		0	0	0	0	0	0
Maximum		0	0	0	0	0	0
Dross Washing	10,868						
Monthly Average		978.12	4,564.56	13,476.32	636,864.80	108,680.0	130,416.0
Maximum		1,086.80	11,085.36	32,930.04	1,445,444.0	108,680.0	163,020.0
Demagging Wet Air Pollution Control	800						
Monthly Average		72.0	336.0	992.0	46,880.0	8,000.0	9,600.0
Maximum		80.0	816.0	2,424.0	106,400.0	8,000.0	12,000.0
Direct Chill Casting Contact Cooling	1,999						
Monthly Average		179.91	839.58	2,478.76	117,141.40	19,990.0	23,988.0
Maximum		199.90	2,038.98	6,056.97	265,867.0	19,990.0	29,985.0
Stationary Casting Contact Cooling	0						
Monthly Average		0	0	0	0	0	0
Maximum		0	0	0	0	0	0
Shot Casting Contact Cooling	0						
Monthly Average		0	0	0	0	0	0
Maximum		0	0	0	0	0	0

*Conventional pollutants are controlled by NSPS only.

Table II-18

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)			
		Cu	Pb	Ni	TSS*
PRIMARY ELECTROLYTIC COPPER REFINING					
Anode and Cathode Rinsing	0				
Monthly Average		0	0	0	0
Maximum		0	0	0	0
Spent Electrolyte	0				
Monthly Average		0	0	0	0
Maximum		0	0	0	0
Casting Contact Cooling	498				
Monthly Average		303.78	44.82	184.26	5,976.0
Maximum		637.44	49.80	273.90	7,470.0
Casting Wet Air Pollution Control	0				
Monthly Average		0	0	0	0
Maximum		0	0	0	0
By-Product Recovery	0				
Monthly Average		0	0	0	0
Maximum		0	0	0	0

*Conventional pollutants are controlled by NSPS only.

Table II-19

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg) Pb	Zn	TSS*
PRIMARY LEAD				
Blast Furnace Slag Granulation	0			
Monthly Average		0	0	0
Maximum		0	0	0
Blast Furnace Wet Air Pollution Control	0			
Monthly Average		0	0	0
Maximum		0	0	0
Zinc Fuming Furnace Wet Air Pollution Control	0			
Monthly Average		0	0	0
Maximum		0	0	0
Dross Reverberatory Wet Air Pollution Control	0			
Monthly Average		0	0	0
Maximum		0	0	0
Dross Reverberatory Furnace Granulation	0			
Monthly Average		0	0	0
Maximum		0	0	0
Hard Lead Refining Wet Air Pollution Control	0			
Monthly Average		0	0	0
Maximum		0	0	0
Hard Lead Refining Slag Granulation	0			
Monthly Average		0	0	0
Maximum		0	0	0

*Conventional pollutants are controlled by NSPS only.

Table II-20

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)				
		Cd	Cu	Pb	Zn	TSS*
PRIMARY ZINC						
Zinc Reduction Furnace Wet Air Pollution Control	1,668					
Monthly Average		133.46	1,017.66	150.15	700.69	20,019.60
Maximum		333.66	2,135.42	166.83	1,701.67	25,024.50
Leaching	1,310					
Monthly Average		104.80	799.10	117.90	550.20	15,720.0
Maximum		262.0	1,676.80	131.0	1,336.20	19,650.0
Leaching Wet Air Pollution Control	0					
Monthly Average		0	0	0	0	0
Maximum		0	0	0	0	0
Cathode and Anode Washing	19,850					
Monthly Average		1,588.0	12,108.50	1,786.50	8,337.0	238,200.0
Maximum		3,970.0	25,408.0	1,985.0	20,247.0	297,750.0
Casting Wet Air Pollution Control	257					
Monthly Average		20.56	156.77	23.13	107.94	3,084.0
Maximum		51.40	328.96	25.70	262.14	3,855.0
Casting Contact Cooling	181					
Monthly Average		14.48	110.41	16.29	76.02	2,172.0
Maximum		36.20	231.68	18.10	184.62	2,715.0
Cadmium Plant	6,171					
Monthly Average		493.68	3,764.31	555.39	2,591.82	74,052.0
Maximum		1,234.20	7,898.88	617.10	6,294.42	92,565.0

*Conventional pollutants are controlled by NSPS only.

Table II-21

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)					
		As	Cd	Cu	Pb	Zn	TSS*
METALLURGICAL ACID PLANTS							
Acid Plant Blowdown	2,554						
Monthly Average		1,455.78	204.32	1,557.94	229.86	1,072.68	30,648.0
Maximum		3,550.06	510.80	3,269.12	255.40	2,605.08	38,310.0

*Conventional pollutants are controlled by NSPS only.

Table II-22

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg) Pb	Se	Zn	Ammonia	TSS*
PRIMARY TUNGSTEN						
Tungsten Acid Rinse	47,600					
Monthly Average		4,284.0	17,612.0	19,992.0	2,789,360.0	571,200.0
Maximum		4,760.0	39,032.0	48,552.0	6,330,800.0	174,000.0
Acid Leach Wet Air Pollution Control	3,770					
Monthly Average		339.30	1,394.90	1,583.40	220,922.0	45,240.0
Maximum		377.0	3,091.40	3,845.40	501,410.0	56,550.0
Alkali Leach Wash	46,700					
Monthly Average		4,203.0	17,279.0	19,614.0	2,736,620.0	560,400.0
Maximum		4,670.0	38,294.0	47,634.0	6,211,100.0	700,500.0
Ion-Exchange Raffinate	51,200					
Monthly Average		4,608.0	41,984.0	21,504.0	3,000,320.0	614,400.0
Maximum		5,120.0	18,944.0	52,224.0	6,809,600.0	768,000.0
Calcium Tungstate Precipitate	37,299					
Monthly Average		3,348.0	13,764.0	15,624.0	2,179,920.0	446,400.0
Maximum		3,720.0	30,504.0	37,944.0	4,947,600.0	558,000.0
Crystallization and Drying of Ammonium Paratungstate	0					
Monthly Average		0	0	0	0	0
Maximum		0	0	0	0	0

Table II-22 (Continued)

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg) Pb	Se	Zn	Ammonia	TSS*
PRIMARY TUNGSTEN (Cont.)						
Ammonium Paratungstate Conversion to Oxides Wet Air Pollution Control	20,900					
Monthly Average		2,717.0	7,733.0	11,704.0	1,224,740.0	418,000.0
Maximum		3,135.0	17,138.0	27,797.0	2,779,700.0	856,900.0
Reduction to Tungsten Wet Air Pollution Control	7,320					
Monthly Average		658.80	482.85	3,074.40	428,952.0	87,840.0
Maximum		732.0	1,070.10	7,466.40	973,560.0	109,800.0
Reduction to Tungsten Water of Formation	19,400					
Monthly Average		1,746.0	7,178.0	8,148.0	1,136,840.0	232,800.0
Maximum		1,940.0	15,908.0	19,788.0	2,580,200.0	291,000.0

*Conventional pollutants are controlled by NSPS only.

Table II-23

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)				
		Pb	Zn	Fl	Ammonia	TSS*
PRIMARY COLUMBIUM-TANTALUM						
Concentrate Digestion Wet Air Pollution Control	5,156					
Monthly Average		464.07	2,165.65	90,750.88	302,159.18	61,875.60
Maximum		515.63	5,259.43	204,705.11	685,787.90	77,344.50
Solvent Extraction Raffinate	26,916					
Monthly Average		2,422.44	11,304.72	473,721.60	1,577,277.60	322,992.0
Maximum		2,691.60	27,454.32	1,068,565.20	3,579,828.0	403,740.0
Solvent Extraction Wet Air Pollution Control	430					
Monthly Average		38.71	180.64	7,569.76	25,203.86	5,161.20
Maximum		43.01	438.70	17,074.97	57,203.30	6,451.50
Precipitation and Filtration of Metal Salts	247,223					
Monthly Average		22,250.07	103,833.66	4,351,124.80	14,487,267.80	2,966,676.0
Maximum		24,722.30	252,167.46	9,814,753.10	32,880,659.0	3,708,345.0
Metal Salt Drying Wet Air Pollution Control	16,479					
Monthly Average		1,483.11	6,921.18	290,030.40	965,669.40	197,748.0
Maximum		1,647.90	16,808.58	654,216.30	2,191,707.0	247,185.0

Table II-23 (Continued)

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

	Regulatory	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)				
Subcategory/Waste Stream	Flow (1/kkg)	Pb	Zn	Fl	Ammonia	TSS*
PRIMARY COLUMBIUM-TANTALUM (Cont.)						
Reduction of Salt to Metal	352,663					
Monthly Average		31,739.67	148,118.46	6,206,868.80	20,666,051.80	4,231.956.0
Maximum		35,266.30	359,716.26	14,000,721.10	46,904,179.0	5,289,945.0
Reduction of Salt to Metal Wet Air Pollution Control	21,521					
Monthly Average		1,936.89	9,038.82	378,769.60	1,261,130.60	258,252.0
Maximum		2,152.10	21,951.42	854,383.70	2,862,293.0	322,815.0
Consolidation and Casting	0					
Monthly Average		0	0	0	0	0
Maximum		0	0	0	0	0

*Conventional pollutants are controlled by NSPS only.

Table II-24

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)			
		Cu	Zn	Ammonia	TSS*
SECONDARY SILVER					
Film Stripping	1,619,000				
Monthly Average		987,590.0	679,980.0	94,873,400.0	19,428,000.0
Maximum		2,072,320.0	1,651,380.0	215,327,000.0	24,285,000.0
Film Stripping Wet Air Pollution Control	15,580				
Monthly Average		9,503.80	6,543.60	912,988.0	186,960.0
Maximum		19,942.40	15,891.60	2,072,140.0	233,700.0
Precipitation and Filtration of Film Stripping Solutions	1,851,000				
Monthly Average		1,129,110.0	777,420.0	108,468,600.0	22,212,000.0
Maximum		2,369,280.0	1,888,020.0	246,183,000.0	27,765,000.0
Precipitation and Filtration of Film Stripping Solutions Wet Air Pollution Control	15,580				
Monthly Average		9,503.80	6,543.60	912,988.0	186,960.0
Maximum		19,942.40	15,891.60	2,072,140.0	233,700.0
Precipitation and Filtration of Photographic Solutions	854,000				
Monthly Average		520,940.0	358,680.0	50,044,400.0	10,248,000.0
Maximum		1,093,120.0	871,080.0	113,582,000.0	12,810,000.0
Precipitation and Filtration of Photographic Solutions Wet Air Pollution Control	390,300				
Monthly Average		238,083.0	163,926.0	22,871,580.0	4,683,600.0
Maximum		499,584.0	398,106.0	51,909,900.0	5,854,500.0

Table II-24 (Continued)

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)			
		Cu	Zn	Ammonia	TSS*
SECONDARY SILVER (Cont.)					
Electrolytic Refining	24,316				
Monthly Average		14,832.76	10,212.72	1,424,917.60	291,792.0
Maximum		31,124.48	24,802.82	3,234,028.0	364,740.0
Furnace Wet Air Pollution Control	0				
Monthly Average		0	0	0	0
Maximum		0	0	0	0
Casting Contact Cooling	1,204				
Monthly Average		734.44	505.68	70,554.40	14,448.0
Maximum		1,541.12	1,228.08	160,132.0	18,060.0
Casting Wet Air Pollution Control	4,741				
Monthly Average		2,892.01	1,991.22	277,822.60	56,892.0
Maximum		6,068.48	4,835.82	630,553.0	71,115.0
Leaching	2,780				
Monthly Average		1,695.8	1,167.6	162,908.0	33,360.0
Maximum		3,558.4	2,835.6	369,740.0	41,700.0
Leaching Wet Air Pollution Control	142,389				
Monthly Average		86,857.29	59,803.38	8,343,995.40	1,708,668.0
Maximum		182,257.92	145,236.78	18,937,737.0	2,135,835.0

Table II-24 (Continued)

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)			
		Cu	Zn	Ammonia	TSS*
SECONDARY SILVER (Cont.)					
Precipitation and Filtration of Nonphotographic Solutions	98,577				
Monthly Average		60,131.97	41,402.34	5,776,612.20	1,182,924.0
Maximum		126,178.56	100,548.54	13,110,741.0	1,478,655.0
Precipitation and Filtration of Nonphotographic Solutions Wet Air Pollution Control	79,931				
Monthly Average		48,757.91	33,571.02	4,683,956.60	959,172.0
Maximum		102,311.68	81,529.62	10,630,823.0	1,198,965.0

*Conventional pollutants are controlled by NSPS only.

Table II-25

PROPOSED NSPS/PSNS EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (1/kkg)	BAT/PSES EFFLUENT LIMITATIONS (mg/kkg)					
		Sb	As	Pb	Zn	Ammonia	TSS*
SECONDARY LEAD							
Battery Cracking	673						
Monthly Average		578.78	383.61	60.57	282.66	0	8,076.0
Maximum		1,298.89	935.47	67.30	686.46	0	10,095.0
Blast and Reverberatory Furnace Wet Air Pollution Control	2,610						
Monthly Average		2,244.60	1,487.70	234.90	1,096.20	0	31,320.0
Maximum		5,037.30	3,627.90	261.0	2,662.20	0	39,150.0
Kettle Wet Air Pollution Control	0						
Monthly Average		0	0	0	0	0	0
Maximum		0	0	0	0	0	0
Casting Contact Cooling	22.1						
Monthly Average		19.066	12.60	1.99	9.28	0	265.20
Maximum		42.653	30.72	2.21	22.54	0	331.50

*Conventional pollutants are controlled by NSPS only.

Table II-26

BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BCT EFFLUENT LIMITATIONS (mg/kkg)	
		O&G	TSS
PRIMARY ALUMINUM			
Anode Paste Plant Wet Air Pollution Control	1,028		
Monthly Average		12,336.0	20,560.0
Maximum		20,560.0	42,148.0
Anode Bake Plant Wet Air Pollution Control	617		
Monthly Average		7,404.0	12,340.0
Maximum		12,340.0	25,297.0
Cathode Manufacturing	77.5		
Monthly Average		930.0	1,550.0
Maximum		1,550.0	3,177.5
Cathode Reprocessing	952		
Monthly Average		11,424.0	19,040.0
Maximum		19,040.0	39,032.0
Anode Contact Cooling	1,490		
Monthly Average		17,880.0	29,800.0
Maximum		29,800.0	61,090.0
Potline Wet Air Pollution Control	838		
Monthly Average		10,056.0	16,760.0
Maximum		16,760.0	34,358.0
Potroom Wet Air Pollution Control	1,305		
Monthly Average		15,660.0	26,100.0
Maximum		26,100.0	53,505.0
Degassing Wet Air Pollution Control	2,616		
Monthly Average		31,392.0	52,320.0
Maximum		52,320.0	107,256.0
Direct Chill Casting Contact Cooling	1,999		
Monthly Average		23,988.0	39,980.0
Maximum		39,980.0	81,959.0

Table II-26 (Continued)

BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BCT EFFLUENT LIMITATIONS (mg/kkg)	
		O&G	TSS
PRIMARY ALUMINUM (Cont.)			
Continuous Rod Casting Contact Cooling	1,042		
Monthly Average		12,504.0	20,840.0
Maximum		20,840.0	42,722.0
Stationary Casting Contact Cooling	0		
Monthly Average		0	0
Maximum		0	0

Table II-27

BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BCT EFFLUENT LIMITATIONS (mg/kkg) O&G	TSS
SECONDARY ALUMINUM			
Scrap Drying Wet Air Pollution Control	0		
Monthly Average		0	0
Maximum		0	0
Scrap Screening and Milling	0		
Monthly Average		0	0
Maximum		0	0
Dross Washing	10,868		
Monthly Average		130,416.0	217,360.0
Maximum		217,360.0	445,588.0
Demagging Wet Air Pollution Control	800		
Monthly Average		9,600.0	16,000.0
Maximum		16,000.0	32,800.0
Direct Chill Casting Contact Cooling	1,999		
Monthly Average		23,988.0	39,980.0
Maximum		39,980.0	81,959.0
Stationary Casting Contact Cooling	0		
Monthly Average		0	0
Maximum		0	0
Shot Casting Contact Coolng	0		
Monthly Average		0	0
Maximum		0	0

Table II-28

BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BCT EFFLUENT LIMITATIONS (mg/kkg)
		TSS
PRIMARY ELECTROLYTIC COPPER REFINING		
Anode and Cathode Rinsing	120	
Monthly Average		2,400.0
Maximum		4,920.0
Spent Electrolyte	280	
Monthly Average		5,600.0
Maximum		11,480.0
Casting Contact Cooling	1,000	
Monthly Average		20,000.0
Maximum		41,000.0
Casting Wet Air Pollution Control	0	
Monthly Average		0
Maximum		0
By-Product Recovery	600	
Monthly Average		0
Maximum		0

Table II-29

BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BCT EFFLUENT LIMITATIONS (mg/kkg)
		TSS
PRIMARY LEAD		
Blast Furnace Slag Granulation	3,730	
Monthly Average		74,600.0
Maximum		152,930.0
Blast Furnace Wet Air Pollution Control	0	
Monthly Average		0
Maximum		0
Zinc Fuming Furnace Wet Air Pollution Control	426	
Monthly Average		8,520.0
Maximum		17,466.0
Dross Reverberatory Furnace Wet Air Pollution Control	0	
Monthly Average		0
Maximum		0
Dross Reverberatory Furnace Granulation	3,134	
Monthly Average		62,680.0
Maximum		128,494.0
Hard Lead Refinning Wet Air Pollution Control	19,836	
Monthly Average		396,720.0
Maximum		813,276.0
Hard Lead Refining Slag Granulation	0	
Monthly Average		0
Maximum		0

Table II-30

BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BCT EFFLUENT LIMITATIONS (mg/kkg) TSS
PRIMARY ZINC		
Zinc Reduction Furnace Wet Air Pollution Control	1,668	
Monthly Average		33,366.0
Maximum		68,400.30
Leaching	1,310	
Monthly Average		26,200.0
Maximum		53,710.0
Leaching Wet Air Pollution Control	0	
Monthly Average		0
Maximum		0
Cathode and Anode Washing	19,850	
Monthly Average		397,000.0
Maximum		813,850.0
Casting Wet Air Pollution Control	2,570	
Monthly Average		51,400.0
Maximum		105,370.0
Casting Contact Cooling	1,947	
Monthly Average		38,940.0
Maximum		79,827.0
Cadmium Plant	6,171	
Monthly Average		123,420.0
Maximum		253,011.0

Table II-31

BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BCT EFFLUENT LIMITATIONS (mg/kkg)
		TSS
METALLURGICAL ACID PLANTS		
Acid Plant Blowdown	6,079	
Monthly Average		121,580.0
Maximum		249,239.0

Table II-32

BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BCT EFFLUENT LIMITATIONS (mg/kkg) TSS
PRIMARY TUNGSTEN		
Tungsten Acid Rinse	47,600	
Monthly Average		952,000.0
Maximum		1,951,600.0
Acid Leach Wet Air Pollution Control	37,700	
Monthly Average		754,000.0
Maximum		1,545,700.0
Alkali Leach Wash	46,700	
Monthly Average		934,000.0
Maximum		1,914,700.0
Ion-Exchange Raffinate	51,200	
Monthly Average		1,024,000.0
Maximum		2,099,200.0
Calcium Tungstate Precipitate Wash	37,200	
Monthly Average		744,000.0
Maximum		1,525,200.0
Crystallization and Drying of Ammonium Paratungstate	0	
Monthly Average		0
Maximum		0
Ammonium Paratungstate Conversion to Oxides Wet Air Pollution Control	20,900	
Monthly Average		418,000.0
Maximum		856,900.0
Reduction to Tungsten Wet Air Pollution Control	73,200	
Monthly Average		1,464,000.0
Maximum		3,001,200.0
Reduction to Tungsten Water of Formation	19,400	
Monthly Average		388,000.0
Maximum		795,400.0

Table II-33

BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BCT EFFLUENT LIMITATIONS (mg/kkg)
		TSS
PRIMARY COLUMBIUM-TANTALUM		
Concentrate Digestion Wet Air Pollution Control	10,915	
Monthly Average		218,300.0
Maximum		447,515.0
Solvent Extraction Raffinate	26,916	
Monthly Average		538,320.0
Maximum		1,103,556.0
Solvent Extraction Wet Air Pollution Control	4,301	
Monthly Average		86,028.0
Maximum		176,357.40
Precipitation and Filtration of Metal Salts	247,223	
Monthly Average		4,944,460.0
Maximum		10,136,143.0
Metal Salt Drying Wet Air Pollution Control	83,643	
Monthly Average		1,672,860.0
Maximum		3,429,363.0
Reduction of Salt to Metal	352,663	
Monthly Average		7,053,260.0
Maximum		14,459,183.0
Reduction of Salt to Metal Wet Air Pollution Control	21,521	
Monthly Average		430,420.0
Maximum		882,361.0
Consolidation and Casting Contact Cooling	0	
Monthly Average		0
Maximum		0

Table II-34

BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BCT EFFLUENT LIMITATIONS (mg/kkg)
		TSS
SECONDARY SILVER		
Film Stripping	1,619,000	
Monthly Average		32,380,000.0
Maximum		66,379,000.0
Film Stripping Wet Air Pollution Control	15,580	
Monthly Average		311,600.0
Maximum		638,780.0
Precipitation and Filtration of Film Stripping Solutions	1,851,000	
Monthly Average		37,020,000.0
Maximum		75,891,000.0
Precipitation and Filtration of Film Stripping Solutions Wet Air Pollution Control	15,580	
Monthly Average		311,600.0
Maximum		638,780.0
Precipitation and Filtration of Photographic Solutions	854,000	
Monthly Average		17,080,000.0
Maximum		35,014,000.0
Precipitation and Filtration of Photographic Solutions Wet Air Pollution Control	390,300	
Monthly Average		7,806,000.0
Maximum		16,002,300.0
Electrolytic Refining	24,316	
Monthly Average		486,320.0
Maximum		996,956.0
Furnace Wet Air Pollution Control	21,519	
Monthly Average		430,380.0
Maximum		882,279.0

Table II-34 (Continued)

BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BCT EFFLUENT LIMITATIONS (mg/kkg) TSS
SECONDARY SILVER (Cont.)		
Casting Contact Cooling	12,035	
Monthly Average		240,700.0
Maximum		493,435.0
Casting Wet Air Pollution Control	4,741	
Monthly Average		94,820.0
Maximum		194,381.0
Leaching	2,780	
Monthly Average		55,600.0
Maximum		113,980.0
Leaching Wet Air Pollution Control	142,389	
Monthly Average		2,847,780.0
Maximum		5,837,949.0
Precipitation and Filtration of Nonphotographic Solutions	98,577	
Monthly Average		1,971,540.0
Maximum		4,041,657.0
Precipitation and Filtration of Nonphotographic Solutions Wet Air Pollution Control	79,931	
Monthly Average		1,598,620.0
Maximum		3,277,171.0

Table II-35

BCT PROPOSED EFFLUENT LIMITATIONS COMPARISON
NONFERROUS METALS MANUFACTURING POINT SOURCE CATEGORY

Subcategory/Waste Stream	Regulatory Flow (l/kkg)	BCT EFFLUENT LIMITATIONS (mg/kkg) TSS
SECONDARY LEAD		
Battery Cracking	940	
Monthly Average		18,800.0
Maximum		38,540.0
Blast and Reverberatory Furnace Wet Air Pollution Control	3,380	
Monthly Average		67,600.0
Maximum		138,580.0
Kettle Wet Air Pollution Control	0	
Monthly Average		0
Maximum		0
Casting Contact Cooling	221	
Monthly Average		4,424.0
Maximum		9,069.20

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

The Federal Water Pollution Control Act Amendments of 1972 established a comprehensive program to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters," under Section 101(a). By July 1, 1977, existing industrial dischargers were required to achieve "effluent limitations requiring the application of the best practicable control technology currently available" (BPT), under Section 301(b)(1)(A); and by July 1, 1983, these dischargers were required to achieve "effluent limitations requiring the application of the best available technology economically achievable . . . which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants" (BAT), under Section 301(b)(2)(A). New industrial direct dischargers were required to comply with Section 306 new source performance standards (NSPS), based on best available demonstrated technology; existing and new dischargers to publicly owned treatment works (POTW) were subject to pretreatment standards under Sections 307(b) (PSES) and (c) (PSNS), respectively, of the Act. While the requirements for direct dischargers were to be incorporated into National Pollutant Discharge Elimination System (NPDES) permits issued under Section 402 of the Act, pretreatment standards were made enforceable directly against discharges to a POTW (indirect dischargers). Although Section 402(a)(1) of the 1972 Act authorized the setting of NPDES permit requirements for direct dischargers on a case-by-case basis, Congress intended that, for the most part, control requirements would be based on the degree of effluent reduction attainable through the application of BPT and BAT. Moreover, Sections 304(c) and 306 of the Act required promulgation of regulations for new sources (NSPS); and Sections 304(f), 307(b), and 307(c) required promulgation of regulations for pretreatment standards. In addition to these regulations for designated industry categories, Section 307(a) of the Act required the Administrator to promulgate effluent standards applicable to all dischargers of toxic pollutants. Finally, Section 301(a) of the Act authorized the Administrator to prescribe any additional regulations "necessary to carry out his functions" under the Act.

EPA was unable to promulgate many of these regulations by the dates contained in the Act. In 1976, EPA was sued by several environmental groups and in settlement of this lawsuit, EPA and the plaintiffs executed a "Settlement Agreement," which was approved by the Court. This Agreement required EPA to develop a program and adhere to a schedule for promulgating 21 major industries' BAT effluent limitations guidelines, pretreatment standards, and new source performance standards for 65 "priority" pollutants and classes of pollutants. See Settlement Agreement in Natural Resources Defense Council, Inc. v. Train, 8 ERC 2120 (D.D.C. 1976), *modified* 12 ERC 1833 (D.D.C. 1979).

On December 27, 1977, the President signed into law amendments to the Federal Water Pollution Control Act (P.L. 95-217). The Act, as amended, is commonly referred to as the Clean Water Act. Although this Act makes several important changes in the federal water pollution control program, its most significant feature is its incorporation of several of the basic elements of the Settlement Agreement program for toxic pollution control. Sections 301(b)(2)(A) and 301(b)(2)(C) of the Act now require the achievement, by July 1, 1984, of effluent limitations requiring application of BAT for toxic pollutants, including the 65 priority pollutants and classes of pollutants (the same priority pollutants as listed in *Natural Resources Defense Council* v. *Train*), which Congress declared toxic under Section 307(a) of the Act. Likewise, EPA's programs for new source performance standards and pretreatment standards are now aimed principally at control of these toxic pollutants. Moreover, to strengthen the toxics control program, Congress added Section 304(e) to the Act, authorizing the Administrator to prescribe "best management practices" (BMP) to prevent the release of toxic and hazardous pollutants from plant site runoff, spillage or leaks, sludge or waste disposal, and drainage from raw material storage associated with, or ancillary to, the manufacturing or treatment process.

In keeping with its emphasis on toxic pollutants, the Clean Water Act also revised the control program for nontoxic pollutants. Instead of BAT for "conventional" pollutants identified under Section 304(a)(4) (including biological oxygen demand, suspended solids, oil and grease, fecal coliform, and pH), the new Section 301(b)(2)(E) requires achievement, by July 1, 1984, of "effluent limitations requiring the application of the best conventional pollutant control technology" (BCT). The factors considered in assessing BCT for an industry include a two-part "cost-reasonableness" test [Section 304(b)(4)(B)], *American Paper Institute* v. *EPA*, 660 F.2d 954 (4th Cir. 1981). The first part compares the cost for private industry to reduce its conventional pollutants with the costs to publicly owned treatment works for similar levels of reduction in their discharge of pollutants. The second part examines the cost effectiveness of additional industrial treatment beyond BPT. For nontoxic, nonconventional pollutants, Sections 301(b)(2)(A) and (b)(2)(F) require achievement of BAT effluent limitations within three years after their establishment or not later than July 1, 1984.

The purpose of this report is to provide the supporting technical data regarding water use, pollutants, and treatment technologies for BPT, BAT, NSPS, PSES or PSNS effluent limitations that EPA is proposing for the nonferrous metals manufacturing category under Sections 301, 304, 306, 307, and 501 of the Clean Water Act.

PRIOR EPA REGULATIONS

EPA already has promulgated effluent limitations and pretreatment standards for certain nonferrous metals manufacturing subcategories. These regulations, and the technological basis therefore, are summarized below.

Primary Aluminum Subcategory. EPA has promulgated BPT, BAT, NSPS, and PSNS in this subcategory. 39 FR 12822 (March 26, 1974). BPT is based on lime precipitation and sedimentation technology. BAT is based on this technology and flow reduction; NSPS and PSNS are based on the same technology and additional flow reduction.

Secondary Aluminum Subcategory. Existing regulations in this subcategory cover BPT, BAT, NSPS, PSES and PSNS. 39 FR 12822 (March 26, 1974) and 41 FR 54854 (December 15, 1976) (establishing pretreatment standards). BPT is based on lime precipitation and sedimentation with pH adjustment to control ammonia. BAT is no discharge of wastewater pollutants, PSES is based on oil skimming, pH adjustment and ammonia air stripping, while NSPS and PSNS are based on lime precipitation and sedimentation and flow reduction. (Promulgated NSPS and PSNS are less stringent than BAT and PSES because the processes believed to be necessary to achieve zero discharge were not yet demonstrated in 1974 or 1976, but it was believed that they would be demonstrated at the time of the BAT and PSES compliance dates.)

Primary Copper Smelting. Existing regulations cover BPT and BAT. The amended BPT, the most recently promulgated regulation, is no discharge of process wastewater pollutants subject to an exception for unlimited discharge of the volume of water falling within impoundments in excess of the 10-year, 24-hour storm (known as a catastrophic precipitation event) when a storm of at least that magnitude occurred. See 45 FR 44926 (July 2, 1980). Existing BAT, promulgated earlier (40 FR 8523 (February 27, 1975)), is presently less stringent than BPT, allowing as exemptions to zero discharge a similar unlimited discharge for stormwater (except the allowance is for a volume of wastewater in excess of a 25-year, 10-hour storm), and a further discharge during any calendar month equal in volume to the difference between precipitation on and evaporation from the impoundment during that month. This later discharge is subject to concentration-based limitations.

Primary Electrolytic Copper Refining. Existing regulations cover BPT and BAT. The BPT regulation for this subcategory allows a mass-based continuous discharge based on lime precipitation and sedimentation. 45 FR 44926 (July 2, 1980). The BAT regulation, promulgated earlier (40 FR 8524 (February 27, 1975)) is impoundment rather than hardware-based, and establishes a mass-based continuous discharge limitation, based on flow reduction, lime precipitation, sedimentation, and the same allowances for catastrophic stormwater discharge and net precipitation discharge described for primary copper smelting, previously. (Refiners located in areas of net evaporation, however, cannot discharge process wastewaters, based on the use of solar evaporation. The monthly net precipitation and catastrophic discharges may be discharged.)

Secondary Copper. EPA has established BPT, BAT and PSES in this subcategory. BPT and BAT, based on the presence of impoundments (or cooling tower circuits), require no discharge of process wastewater pollutants with allowances for catastrophic stormwater discharge and net precipitation discharge as described above when impoundments are used instead of cooling tower circuits. See 40 FR 8526 (February 27, 1975). PSES, promulgated later (41 FR 54854 (December 15, 1976)) is based on lime precipitation and sedimentation.

Primary Lead. The existing BPT and BAT limitations in this subcategory are based on impoundments. See 40 FR (February 27, 1975). These limitations provide for no discharge of process wastewater pollutants, with exemptions for catastrophic stormwater and net precipitation discharge of acid plant blowdown (subject to mass limitations) and monthly net precipitation on impoundments. The existing limitations do not apply to primary lead refineries not on-site with a smelter.

Primary Zinc. We have promulgated BPT and BAT in this subcategory. See 40 FR 8528 (February 27, 1975). These limitations are based on lime precipitation and sedimentation technology for BPT, with flow reduction added for BAT.

Metallurgical Acid Plants. This subcategory was established in 1980, and presently includes only acid plants (*i.e.*, plants recovering by-product sulfuric acid from sulfur dioxide smelter air emissions) associated with primary copper smelting operations. See 45 FR 44926. Primary lead and zinc plants also have associated acid plants, but their discharges presently are covered under the primary lead and zinc subcategories. BPT for copper smelting acid plants is based on lime precipitation and sedimentation.

METHODOLOGY

Approach of Study

The nonferrous metals manufacturing category includes plants producing primary metals from ore concentrates and recovering secondary metals from recycled metallic wastes (aluminum cans, lead batteries, etc.). Because of the diversity of the nonferrous metals manufacturing category, EPA has divided it into separate segments (nonferrous metals manufacturing Phase I and nonferrous metals manufacturing Phase II).

The proposed regulatory strategy for Phase I nonferrous metals manufacturing addresses 12 subcategories: primary aluminum, copper smelting, copper electrolytic refining, lead, zinc, columbium-tantalum, and tungsten; secondary aluminum, silver, copper, and lead; and metallurgical acid plants. Nonferrous metals manufacturing Phase II, containing an additional 21 primary metals or metal groups, 15 secondary metals or metal groups, and bauxite refining (Table III-2) will be considered separately and is scheduled for proposal in September, 1983. EPA has also studied the segments of the nonferrous metals industry associated with forming and casting. Proposed regulations for aluminum forming (47 FR 52626), copper forming (47 FR 51278) and metal molding and casting (47 FR 51512) were issued in November, 1982. The forming of nonferrous metals other than copper and aluminum will be addressed in a proposed regulation that is scheduled for September, 1983. A group of metals including six primary metals and five secondary metals, was included in a Paragraph 8 affidavit submitted pursuant to the Settlement Agreement: primary arsenic, antimony, barium, bismuth, calcium, and tin; secondary beryllium, cadmium, molybdenum, tantalum, and babbitt. These metals were excluded from regulation because the manufacturing processes do not use water or are regulated by toxics limitations in other categories (ferroalloys and inorganic chemicals).

EPA gathered and evaluated technical data in the course of developing these guidelines in order to perform the following tasks:

1. To profile the category with regard to the production, manufacturing processes, geographical distribution, potential wastewater streams, and discharge mode of nonferrous metals manufacturing plants.

2. To subcategorize, if necessary, in order to permit regulation of the nonferrous metals manufacturing category in an equitable and manageable way.

3. To characterize wastewater, detailing water use, wastewater discharge, and the occurrence of toxic, conventional, and nonconventional pollutants, in waste streams from nonferrous metals manufacturing processes.

4. To select pollutant parameters--those toxic, nonconventional, or conventional pollutants present at significant concentrations in wastewater streams--that should be considered for regulation.

5. To consider control and treatment technologies and select alternative methods for reducing pollutant discharge in this category.

6. To evaluate the costs of implementing the alternative control and treatment technologies.

7. To present possible regulatory alternatives.

Data Collection and Methods of Evaluation

Data on the nonferrous metals manufacturing category were gathered from previous EPA studies, literature studies, inquiries to federal and state environmental agencies, trade association contacts and the manufacturers themselves. Meetings were also held with industry representatives and the EPA. All known companies within the nonferrous metals manufacturing category were sent data collection portfolios to solicit specific information concerning each facility. Finally, a sampling program was carried out at 46 plants. The sampling program consisted of screen sampling and analysis at 10 facilities to determine the presence of a broad range of pollutants and verification at 36 plants to quantify the pollutants present in the wastewater. Specific details of the sampling program and information from the above data sources are presented in Section V. Details on selection of plants for sampling, and analytical results, are contained in Section V of each of the subcategory supplements.

Literature Review. EPA reviewed and evaluated existing literature for background information to clarify and define various aspects of the nonferrous metals manufacturing category and to determine general characteristics and trends in production processes and wastewater treatment technology. Review of current literature continued throughout the development of these limitations and standards. Information gathered in this review was used, along with information from other sources as discussed below, in the following specific areas:

- Introduction (Section III of each of the subcategory supplements) - description of production processes and the associated lubricants and wastewater streams.

- Subcategorization (Section IV of each of the subcategory supplements) - identification of differences in manufacturing process technology and their potential effect on associated wastewater streams.

- Selection of Pollutant Parameters (Section VI) - information regarding the toxicity and potential sources of the pollutants identified in wastewater from nonferrous metals manufacturing processes.

- Control and Treatment Technology (Section VII) - information on alternative controls and treatment and corresponding effects on pollutant removal.

- Costs (Section VIII) - formulation of the methodology for determining the current capital and annual costs to apply the selected treatment alternatives.

Existing Data. Previous EPA studies of the following nonferrous metals manufacturing subcategories were reviewed.

Primary Aluminum
Secondary Aluminum
Primary Copper
Secondary Copper
Primary Lead
Primary Zinc
Miscellaneous Nonferrous Metals (Including Secondary Lead, Columbium-Tantalum, Primary and Secondary Germanium, Primary Magnesium, Primary Beryllium, and Secondary Zinc)

The available information included a summary of the category describing the production processes, the wastewater characteristics associated with the processes, recommended pollutant parameters requiring control; applicable end-of-pipe treatment technologies for wastewaters; effluent characteristics resulting from this treatment, and a background bibliography. Also included in these studies were detailed production and sampling information for many plants.

The concentration or mass loading of pollutant parameters in wastewater effluent discharges are monitored and reported as required by individual state agencies. These historical data are available from NPDES monitoring reports.

Frequent contact has been maintained with industry personnel. Contributions from these sources were particularly useful for clarifying differences in production processes.

Data Collection Portfolios. EPA conducted a survey of the nonferrous metals manufacturing plants to gather information regarding plant size, age and production, the production processes used, and the quantity, treatment, and disposal of wastewater generated at these plants. This information was requested in data collection portfolios (dcp) mailed to all companies known or believed to belong to the nonferrous metals manufacturing category. A listing of the companies comprising the nonferrous metals industry (as classified by standard industrial code numbers) was compiled by consulting trade associations and the U.S. Bureau of Mines.

In all, dcp were sent to 319 firms (416 plants). In many cases, companies contacted were not actually members of the nonferrous metals manufacturing category as it is defined by the Agency. Where firms had nonferrous metals manufacturing operations at more than one location, a dcp was returned for each plant.

If the dcp were not returned, information on production processes, sources of wastewater and treatment technology at these plants was collected by telephone interview. The information so gathered was validated by sending a copy of the information recorded to the party consulted. The informaton was assumed to be correct as recorded if no reply was received in 30 days. In total, more than 95 percent of the category was contacted either by mail or by telephone.

A total of 314 dcp applicable to the nonferrous metals manufacturing category were returned. A breakdown of these facilities by type of metal processed is presented in Table III-3.

The dcp responses were interpreted individually, and the following data were documented for future reference and evaluation:

- Company name, plant address, and name of the contact listed in the dcp.
- Plant discharge status as direct (to surface water), indirect (to POTW), or zero discharge.
- Production process streams present at the plant, as well as associated flow rates; production rates; process capacities; operating hours; wastewater treatment, reuse, or disposal methods; and the quantity and nature of process chemicals.
- Capital and annual treatment costs.
- Availability of pollutant monitoring data provided by the plant.

The summary listing of this information provided a consistent, systematic method of evaluating and summarizing the dcp responses. In addition, procedures were developed to simplify subsequent analyses. The procedures developed had the following capabilities:

- Selection and listing of plants containing specific production process streams or treatment technologies.
- Summation of the number of plants containing specific process waste streams and treatment combinations.
- Calculation of the percent recycle present for specific waste streams and summation of the number of plants recycling these waste streams within various percent recycle ranges.
- Calculation of annual production values associated with each process stream and summation of the number of plants with these process streams having production values within various ranges.
- Calculation of water use and discharge from individual process streams.

The calculated information and summaries were used in developing these effluent limitations and standards. Summaries were used in the category profile, evaluation of subcategorization, and analysis of in-place treatment and control technologies. Calculated information was used in the determination of water use and discharge values for the conversion of pollutant concentrations to mass loadings.

GENERAL PROFILE OF THE NONFERROUS METALS MANUFACTURING CATEGORY

The nonferrous metals manufacturing point source category encompasses the primary smelting and refining of nonferrous metals (Standard Industrial Classification (SIC) 333) and the secondary smelting and refining of nonferrous metals (SIC 334). The category does not include the mining and concentrating of ores, rolling, drawing, or extruding of metals, or scrap metal collection and preliminary grading.

Nonferrous metal manufacturers include processors of ore concentrates or other virgin materials (primary) and processors of scrap (secondary). Metals produced as by- or co-products of primary metals are themselves considered primary metals. For example, silver produced from primary copper anode slimes is considered to be primary silver, rather than secondary.

The nonferrous metals manufacturing category is quite complex and the production process for a specific metal is dictated by the characteristics of raw materials, and economics of by-product recovery, as well as the chemistry of the metals. Some metals, such as primary aluminum, are produced by essentially one process, while others, like copper and zinc, may be produced either pyrometallurgically or electrometallurgically. By-products and co-products are also important considerations for some industries. Many nonferrous metals are co-products or by-products of the smelting or refining of the base metals (copper, lead, and zinc). For example, all or almost all of the domestic production of arsenic, rhenium, palladium, selenium, and tellurium during 1975 was as a by-product or co-product of copper. About one-third of all domestic production of silver and gold was a copper by- or co-product. Copper itself is a by-product of lead, zinc, silver, and gold production. Other metals, such as aluminum and tungsten, are produced without important by-products. The co-product or by-product metals leave the production facilities where they were generated in a variety of forms and states of refinement, i.e., as concentrates, as unrefined materials in the form of slags, drosses, slimes or sludges, or as refined or alloyed metals.

Base-metal residues are interchanged among copper, lead, and zinc processors. Other metal-rich residues are shipped to centralized processing facilities where they are selectively extracted and refined. The production of co- or by-product nonferrous metals generally involves relatively small operations.

Employment data are given in the dcp responses for 314 plants. These plants report a total of 61,000 workers involved in nonferrous metals manufacturing Phase I plants. Industry production figures show that the aluminum, copper, lead and zinc producers dominate the industry in terms of tonnage.

One hundred and eighty plants (57 percent) indicated that no wastewater from nonferrous metals manufacturing operations is discharged to either surface waters or a POTW. Of the remaining 135, 76 (25 percent) discharge an effluent from nonferrous metals manufacturing directly to surface waters, and 58 (18 percent) discharge indirectly, sending nonferrous metals manufacturing effluent through a POTW.

EPA recognizes that plants sometimes combine process and nonprocess wastewater prior to treatment and discharge. Pollutant discharge allowances will be established under this regulation only for nonferrous metals manufacturing process wastewater, not the nonprocess wastewaters. The flows and wastewater characteristics are a function of the plant layout and water handling practices. As a result, the pollutant discharge effluent limitation for nonprocess wastewater streams will be prepared by the permitting authority. A discussion of how a permitter might construct a permit for an integrated facility is presented in Section IX, Building Blocks.

Section III of each of the subcategory supplements presents a detailed profile of the plants in each subcategory and describes the production processes involved. In addition, the following specific information is presented:

1. Raw materials,
2. Manufacturing process,
3. Geographic locations of manufacturing plants,
4. Age of plants by discharge status,
5. Production ranges by discharge status, and
6. Summary of waste streams for each process.

Table III-1

CURRENTLY PROMULGATED LIMITATIONS AND STANDARDS - NONFERROUS METALS MANUFACTURING

Subcategory	BPT	BAT	NSPS	PSES	PSNS
Primary Aluminum	LS	LS,FR	LS,FR[1]	--	LS,FR[1]
Secondary Aluminum	LS, PH	ND	LS,FR	OS,pH,AS	LS,FR
Primary Copper Smelting	ND[2]	ND[2,3]	--	--	--
Primary Electrolytic Copper Refining	LS	LS,FR[2,3,4]	--	--	--
Secondary Copper	ND[2,3]	ND[2,3]	--	LS	--
Primary Lead	ND[2,3]	ND[2,3]	--	--	--
Primary Zinc	LS	LS,FR	--	--	--
Metallurgical Acid Plants[4]	LS	--	--	--	--
Primary Tungsten	--	--	--	--	--
Primary Columbium-Tantalum	--	--	--	--	--
Secondary Silver	--	--	--	--	--
Secondary Lead	--	--	--	--	--

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[1] Includes additional flow reduction beyond BAT.

[2] Allows a discharge without limitation during a 10-year, 24-hour rainfall (or 25-year, 24-hour rainfalls at BAT) for stormwater falling on the wastewater cooling or settling pond.

[3] Allows a discharge, subject to concentration limitations, for a flow equal to the net monthly precipitation on the wastewater settling pond.

[4] Copper acid plants only; zinc and lead acid plants are currently covered in the primary zinc and primary lead subcategories.

LS = lime precipitation and sedimentation.
FR = flow reduction.
ND = no discharge.
OS = oil skimming.
pH = pH adjustment.
AS = ammonia air stripping.

Table III-2

NONFERROUS METALS CONSIDERED FOR REGULATION UNDER PHASE II

Primary Metals

Beryllium
Boron
Cesium
Cobalt
Gallium
Germanium
Gold
Hafnium
Indium
Lithium
Magnesium
Mercury
Molybdenum
Nickel
Platinum Group
Rare Earths
Rhenium
Rubidium
Titanium
Uranium
Zirconium

Secondary Metals

Boron
Cobalt
Columbium
Germanium
Indium
Magnesium
Mercury
Nickel
Plutonium
Precious Metals
Tin
Titanium
Tungsten
Uranium
Zinc

Bauxite Refining

Table III-3

BREAKDOWN OF DCP RESPONDENTS BY TYPE OF METAL PROCESSED

Subcategory	Number of Plants
Primary Aluminum	31
Secondary Aluminum	55
Primary Copper Smelting	20
Primary Electrolytic Copper Refining	15
Secondary Copper	31
Primary Lead	7
Secondary Lead	69
Primary Zinc	7
Primary Tungsten	8
Primary Columbium-Tantalum	5
Secondary Silver	44
Metallurgical Acid Plants*	22
TOTAL	314

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*Information about acid plants was reported along with the primary copper, lead and zinc plant responses indicated above.

SECTION IV

INDUSTRY SUBCATEGORIZATION

Subcategorization should take into account pertinent industry characteristics, manufacturing process variations, wastewater characteristics, and other factors. Effluent limitations and standards establish mass limitations on the discharge of pollutants which are applied, through the permit issuance process, to specific dischargers. To allow the national standard to be applied to a wide range of sizes of production units, the mass of pollutant discharge must be referenced to a unit of production. This factor is referred to as a production normalizing parameter and is developed in conjunction with subcategorization.

Division of the category into subcategories provides a mechanism for addressing process and product variations which result in distinct wastewater characteristics. The selection of production normalizing parameters provides the means for compensating for differences in production rates among plants with similar products and processes within a uniform set of mass-based effluent limitations and standards.

This subcategorization analysis is actually an ongoing process. The first subcategories (bauxite refining, primary aluminum smelting, and secondary aluminum smelting) were established in a 1973 Agency rulemaking. Since that time, some subcategories have been modified. New subcategories have been added in 1975 and then again in 1980.

A comprehensive analysis of each factor that might warrant separate limitations for different segments of the industry has led the Agency to propose the following subcategorization scheme for proposal of BPT and BAT effluent limitations guidelines and PSNS, PSES and NSPS:

1. Primary Aluminum Smelting
2. Secondary Aluminum Smelting
3. Primary Copper Smelting
4. Primary Copper Electrolytic Refining
5. Secondary Copper
6. Primary Lead
7. Primary Zinc
8. Metallurgical Acid Plants
9. Primary Tungsten
10. Primary Columbium/Tantalum
11. Secondary Silver
12. Secondary Lead

Most of these subcategories are further segmented into subdivisions for the development of effluent limitations; these subdivisions are enumerated and discussed in the subcategory supplements to this document.

SUBCATEGORIZATION BASIS

Technology-based effluent limitations are based primarily upon the treatability of pollutants in wastewaters generated by the category under review. The treatability of these pollutants is, of course, directly related to the flow and characteristics of the untreated wastewater, which in turn can be affected by factors inherent to a processing plant in the category. Therefore, these factors and the degree to which each influences wastewater flow and characteristics form the basis for subcategorization of the category, i.e., those factors which have a strong influence on untreated wastewater flow and characteristics are applied to the category to subcategorize it in an appropriate manner.

The list of potential subcategorization factors considered for the nonferrous metals manufacturing category include:

1. Metal products, co-products, and by-products;
2. Raw materials;
3. Manufacturing processes;
4. Product form;
5. Plant location;
6. Plant age;
7. Plant size;
8. Air pollution control methods;
9. Meteorological conditions;
10. Treatment costs;
11. Solid waste generation and disposal;
12. Number of employees;
13. Total energy requirements (manufacturing process and waste treatment and control); and
14. Unique plant characteristics.

For the reasons discussed below, the metal or other products, the raw materials, and the manufacturing process were discovered to have the greatest influence on wastewater flow charateristics and treatability, and thus ultimately on the appropriateness of effluent limitations. These three factors were used to subcategorize the category. As mentioned previously, further division of some subcategories is warranted based on the sources of wastewaters (manufacturing processes) within the plant. Each manufacturing process generates differing amounts of wastewater and in some instances specific waste streams contain pollutants requiring preliminary treatment to reduce concentrations of oil and grease, ammonia, cyanide, and toxic organics prior to combined treatment. Thus, each subcategory is further subdivided based on the manufacturing processes used. These subdivisions are discussed in the appropriate supplement.

Metal Products, Co-Products, and By-Products

The metal products, co-products, and by-products is the most important factor in identifying subcategories for this category. Subcategorizing on this basis is consistent with the existing division of plants, i.e., plants are identified as (and identify themselves as) zinc plants, lead plants, silver plants, etc. The production of each metal is based on its own raw materials and production processes, which directly affect wastewater volume and charateristics.

Production and refining of metal by-products and co-products generally will be covered by means of separate subcategorizations, and included in the nonferrous metals phase II. There are two exceptions. EPA found that production of the co-product metals columbium and tantalum are inherently allied, so both were considered in a single subcategory. EPA also found that production of by-product cadmium cannot realistically be separated from primary zinc production (due to the relatively small wastewater volume and loadings from cadmium production), and so this wastewater is included under the limitations and standards for primary zinc.

Raw Materials

The raw materials used (ore concentrates or scrap) in nonferrous metals manufacturing determine the reagents used, and to a large extent the wastewater characteristics. Raw materials are significant in differentiating between primary and secondary producers. It is therefore selected as a basis for subcategorization.

Manufacturing Processes

The production processes for each metal are unique and are affected by the raw materials used and the type of end product. The processes used will, in turn, affect the volume and characteristics of the resulting wastewater.

The processes performed (or the air pollution controls used on the process emissions) in the production of nonferrous metals determine the amount and characteristics of wastewater generated and thus are a logical basis for the establishment of subcategories. In this category, however, similar processes may be applied to differing raw materials in the production of different metals yielding different wastewater characteristics. For example, copper, silver, and zinc may all be produced by electrolysis. As a result of these considerations, specific process operation was not generally found to be suitable as a primary basis for subcategorization. However, process variations which result in significant differences in wastewater generation are reflected in the allowances for discrete unit operations within each subcategory (see the discussion of building blocks in Section IX).

In the case of primary copper manufacturing, the production processes used are deemed to be a reasonable basis for subcategorization, even though these processes are sometimes practiced at a single site. This resulted in the establishment of the primary copper smelting subcatgory and the primary copper electrolytic refining subcategory (see Section IV of the Primary Copper Supplement. This is consistent with the structure of the category since smelting and refining are also often conducted at different sites.

Product Form

This factor becomes important when the final product from a plant is actually an intermediate that another plant purchases and processes to render the metal in a different form. An example of this is the production of tungsten, which some plants produce by reducing ammonium paratungstate (APT), an intermediate that may have been produced by another plant. This practice, however, is not found to be common in the category and its effect on wastewater volume and characteristics is not as significant as the factors chosen.

Plant Location

Most plants in the category are located near raw materials sources, transportation centers, markets, and sources of inexpensive energy. While larger primary copper, lead and zinc producers are mainly found near Midwestern and Western ores and are remote from population centers, plentiful and inexpensive electricity in the Pacific Northwest, the Tennessee Valley and upstate New York is important for primary aluminum producers. Secondary producers, on the other hand, are generally located in or near large metropolitan areas. Therefore, primary producers often have more land available for treatment systems than secondary producers. Plant location also may be significant because evaporation ponds can be used only where solar evaporation is feasible and where sufficient land is available. However, location does not significantly affect wastewater characteristics or treatability, and thus different effluent limitations are not warranted based on this factor.

Plant Age

Plants within a given subcategory may have significantly different ages in terms of initial operating year. To remain competitive, however, plants must be constantly modernized.

Plants may be updated by modernizing a particular component, or by installing new components. For example, an old furnace might be equipped with oxygen lances to increase the throughput, or replaced entirely by a new, more efficient furnace. Modernization of production processes and air pollution control equipment produces analogous wastes among all plants producing a given metal, despite the original plant start-up date. While the relative age of a plant may be important in considering the economic impact of a guideline, as a subcategorization factor it does not account for differences in the raw wastewater characteristics. For these reasons, plant age is not selected as a basis for subcategorization.

Plant Size

The size of a plant generally does not affect either the production methods or the wastewater characteristics. Generally, more water is used at larger plants. However, when water use and discharge are normalized on a production basis, no major differences based on plant size are found within the same subcategory. Thus, plant size is not selected as a basis for subcategorization.

Air Pollution Control Methods

Many facilities use wet scrubbers to control emissions which influence wastewater characteristics. In some cases, the type of air pollution control equipment used provides a basis for regulation, because if wet air pollution control is used, an allowance may be necessary for that waste stream, while a plant using only dry systems does not need an allowance for a non-existent waste stream. Therefore, this factor is often selected as a basis for subdivision within some subcategories (i.e., developing an allowance for this unit operation as part of the limitation or standard for the subcategory), but not as a means for subcategorizing the category.

Meteorological Conditions

Climate and precipitation may affect the feasibility of certain treatment methods, e.g., solar evaporation through the use of impoundments is a feasible method of wastewater treatment only in areas of net evaporation. This factor was not selected for subcategorization, however, because plants in the category are located in areas having widely varying meteorological conditions. The differences in wastewater characteristics and treatability are better explained by other factors such as metal products and manufacturing processes, and thus different effluent limitations based on this factor are not warranted.

Solid Waste Generation and Disposal

Physical and chemical characteristics of solid waste generated by the nonferrous metals category are determined by the raw material, process, and type of air pollution control in use. Therefore, this factor does not provide a primary basis for subcategorization.

Number of Employees

The number of employees in a plant does not directly provide a basis for subcategorization because the number of employees does not necessarily reflect the production or process water usage rate at any plant. Because the amount of process wastewater generated is related to the production rates rather than employee number, the number of employees does not provide a definitive relationship to wastewater generation.

Total Energy Requirements

Total energy requirements was not selected as a basis for subcategorization primarily because energy requirements are found to vary widely within this category and are not meaningfully related to wastewater generation and pollutant discharge. Additionally, it is often difficult to obtain reliable energy estimates specifically for production and waste treatment. When available, estimates are likely to include other energy requirements such as lighting, air conditioning, and heating or cooling energy.

Unique Plant Characteristics

Unique plant characteristics such as land availability and water availability do not provide a proper basis for subcategorization because they do not materially affect the raw wastewater characteristics of the plant. Process water availability may indeed be a function of the geography of a plant. However, the impact of limited water supplies is to encourage conservation by recycle and efficient use of water. As explained in Section VII, this is consistent with EPA's approach to establishing limitations for all plants. Therefore, insufficient water availability only tends to encourage the early installation of practices that EPA believes are advisable for the entire category in order to reduce treatment costs and improve pollutant removals.

Limited land availability for constructing a waste treatment facility may affect the economic impact of an effluent limitation. The availability of land for treatment, however, is generally not a major issue in the nonferrous metals manufacturing category. Most primary plants are located on very large sites and land availability would not be a factor. While secondary producers tend to be located in more urban settings, the amount of land available to them for treatment is sufficient for the types of treatment and control technologies considered.

PRODUCTION NORMALIZING PARAMETERS

To ensure equitable regulation of the category, effluent guidelines limitations and standards of performance are established on a production-related basis, i.e., a mass of pollutant per unit of production. In addition, by using these mass-based limitations, the total mass of pollutants discharged is minimized. The underlying premise for mass-based limitations is that pollutant loadings and water discharged from each process are correlated to the amount of material produced on that process. This correlation is calculated as the mass of pollutant or wastewater discharged per unit of production. The units of production are known as production normalizing parameters (PNPs). The type and value of the PNPs vary according to the subcategory or subdivision. In one case it may be the total mass of metal produced from that line while in others it may be some other characteristic parameter. Two criteria are used in selecting the appropriate PNP for a given subcategory or subdivision: (1) maximizing the degree of correlation between the production of metal reflected by the PNP and the corresponding discharge of pollutants, and (2) ensuring that the PNP is easily measured and feasible for use in establishing regulations.

The production normalizing parameter identified for each subcategory or subdivision, and the rationale used in selection are discussed in detail in Section IV of the appropriate supplements.

SECTION V

WATER USE AND WASTEWATER CHARACTERISTICS

This section presents the data collection and data analysis methods used for characterizing water use and wastewater associated with the nonferrous metals manufacturing category. Raw waste and treated effluent sample data, and production normalized water use and wastewater discharge data are presented for each subcategory in Section V of each of the subcategory supplements.

DATA SOURCES

Historical Data

A useful source of long-term or historical data available for nonferrous metals manufacturing plants are the Discharge Monitoring Reports (DMR's) completed as a part of the National Pollutant Discharge Elimination System (NPDES). All applicable DMR's were obtained through the EPA regional offices and state regulatory agencies for the year 1976, the last complete year for which information was available at the time of the initial data collection for this category. (EPA intends to collect additional more recent DMR data for some plants between proposal and promulgation in order to supplement data submitted during the comment period). The DMR's present a summary of the analytical results from a series of samples taken during a given month for the pollutants designated in the plant's permit. In general, minimum, maximum, and average values, in mg/l or lbs/day, are presented for such pollutants as total suspended solids, aluminum, oil and grease, pH, copper, and zinc. The samples are collected from the plant outfall(s), which represents the discharge(s) from the plant. For facilities with wastewater treatment, the DMR's provide a measure of the performance of the treatment system. In theory, these data could then serve as a basis for characterizing treated wastewater from nonferrous metals manufacturing plants; however, there is no influent to treatment information (i.e., paired influent-effluent data) and too little information on the performance of the plant at the time the samples were collected to be the preferred source of data in formulating achievable performance for various types of treatment. They do serve as a set of data that can be used to verify the technology performances presented in Section VII, Control and Treatment Technology (Table VII-19, p. 307).

Data Collection Portfolios

The dcp responses supplied the quantity of nonferrous metal produced during 1976 and the capacity for each operation. When data were supplied, the quantity of wastewater produced by a production process and the quantity of production of that process were added to the data base.

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Data supplied by dcp responses were evaluated, and two flow-to-production ratios were calculated for each stream in each subcategory. The two ratios, water use and wastewater discharge flow, are differentiated by the flow value used in calculation. Water use is defined as the volume of water or other fluid required for a given process per mass of metal product and is therefore based on the sum of recycle and make-up flows to a given process. Wastewater flow discharged after pretreatment or recycle (if these are present) is used in calculating the production normalized flow--the volume of wastewater discharged from a given process to further treatment, disposal, or discharge per mass of metal produced. Differences between the water use and wastewater flows associated with a given stream result from recycle, evaporation, and carryover on the product. The production values used in calculation correspond to the production normalizing parameter, PNP, assigned to each stream, as outlined in Section IV of each of the subcategory supplements.

The production normalized water use and discharge flows were compiled and summarized by stream type (i.e., flows associated with discrete unit operations). The flows are presented in Section V of each of the subcategory supplements. Where appropriate, an attempt was made to identify factors that could account for variations in water use. Concentration data resulting from samples collected during sampling visits were also compiled and summarized for each waste stream. They can also be found in Section V of the subcategory supplements. BPT, BAT, NSPS, BCT, and pretreatment discharge flows are selected for use in calculating the effluent limitations and standards in Sections IX, X, XI, XII, and XII of each of the subcategory supplements.

The regulatory production normalized discharge flows were also used to estimate flows at nonferrous metals manufacturing plants that supplied EPA with only production data in their dcp. Actual discharge flows or estimated flows, when an actual flow was not reported in the dcp, were then used to determine the cost of various wastewater treatment options at these facilities (see Section VIII).

Sampling and Analysis Program

The sampling and analysis program discussed in this section was undertaken primarily to implement the requirements of the 1977 amendments to the Act and of the Settlement Agreement, and to identify pollutants of concern in the nonferrous metals manufacturing point source category, with emphasis on toxic pollutants. EPA and its contractors collected and analyzed samples from 46 nonferrous metals manufacturing facilities.

This section summarizes the purpose of the sampling trips and identifies the sites sampled and parameters analyzed. It also presents an overview of sample collection, preservation, and transportation techniques. Finally, it describes the pollutant parameters quantified, the methods of analyses and laboratories used, the detectable concentration of each pollutant, and the general approach used to ensure the reliability of the analytical data produced.

Site Selection. Information gathered in the data collection portfolios was used to select sites for wastewater sampling for each subcategory. The plants sampled were selected to be representative of the category. Considerations included how well each facility represented the subcategory as indicated by available data, potential problems in meeting technology-based standards, differences in production processes used, number and variety of unit operations generating wastewater, and wastewater treatment in place. Additional details on site selection are presented in Section V of each of the subcategory supplements.

Field Sampling. After selection of the plants to be sampled, each plant was contacted by telephone, and a letter of notification was sent to each plant as to when a visit would be expected. These inquiries led to acquisition of facility information necessary for efficient on-site sampling. The information resulted in selection of the sources of wastewater to be sampled at each plant. The sample points included, but were not limited to, untreated and treated discharges, process wastewater, and partially treated wastewater.

During this program, 36 nonferrous metals manufacturing plants were sampled by the technical contractor and 10 nonferrous metals manufacturing plants (mine/mill/smelter complexes) were sampled by other contractors or by EPA regional personnel, for a total of 46 plants. The distribution of these plants by subcategory is presented in Table V-1.

Wastewater samples were collected in two phases: screening and verification. The purpose of the first phase, screen sampling, was to identify which toxic pollutants were present in the wastewaters from production of the various metals. Screening samples were analyzed for 128 of the 129 toxic pollutants and other pollutants deemed appropriate. (Because an analytical standard for TCDD was judged to be too hazardous to be made generally available, samples were never analyzed for this pollutant. There is no reason to believe that it would be present in nonferrous metal category wastewaters.) A total of 10 plants were selected for screen sampling. Some plants represent operations from more than one subcategory. At least one plant in every subcategory was sampled during the screening phase. Two plants were sometimes screen sampled within a subcategory because the production process was different. For example, both pyrolytic and electrolytic plants were screen sampled in the primary zinc category.

The second phase of sampling, verification sampling, was used to determine whether the pollutants identified by screen sampling are present throughout a subcategory, and if so, at what concentrations. The samples gathered under the verification sampling were analyzed only for those pollutants selected from the screening results.

To reduce the volume of data handled, avoid unnecessary expense, and direct the scope of the sampling program, a number of the pollutants analyzed for during the screen sampling were not analyzed for during the verification sampling. Three sources of information were used for the verification pollutant selection: the pollutants that plant personnel believes or knows are present in their wastewater, the screen sampling analyses, and the pollutants the Agency believes should be present after studying the processes and materials used by the category. If a pollutant was not detected during screen sampling, and if plant personnel and the Agency did not believe it might be present in the wastewater after studying the processes and materials used, verification analyses for that pollutant were not performed.

On the data collection portfolio, the 129 toxic pollutants were listed and each facility was asked to indicate for each particular pollutant "Known to be Present" (KTBP), "Believed to be Present" (BTBP), "Believed to be Absent" (BTBA), or "Known to be Absent" (KTBA). If the pollutant had been analyzed for and detected, the facility was to indicate KTBP, if analyzed for and not detected, KTBA. If the pollutant had not been analyzed, but might be present in the wastewater, the facility was to indicate BTBP, if it could not be present, BTBA. The reported results are tabulated in Section V of each of the subcategory supplements.

After considering the available information, it was determined that analysis of the volatile acid fraction of the toxic organic pollutants could be discontinued for all subcategories in the verification phase. None of these compounds were detected in analysis of screening samples, information gathered from dcp responses and an evaluation of the production processes and raw materials. Other pollutants which were dropped from the verification sample analysis for specific subcategories are discussed in Section V of each of the subcategory supplements.

Sample Collection, Preservation, and Transportation. Collection, preservation, and transportation of samples were accomplished in accordance with procedures outlined in Appendix III of "Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants" (published by the Environmental Monitoring and Support Laboratory, Cincinnati, Ohio, March 1977, revised, April 1977) and in "Sampling Screening Procedure for the Measurement of Priority Pollutants" (published by the EPA Effluent Guidelines Division, Washington, D.C., October 1976). The procedures are summarized in the paragraphs that follow.

Whenever practical, all samples collected at each sampling point were taken from mid-channel at mid-depth in a turbulent, well-mixed portion of the waste stream. Periodically, the temperature and pH of each waste stream sampled were measured on-site.

Each large composite (Type 1) sample was collected in a new 11.4-liter (3-gallon), narrow-mouth glass jug that had been washed with detergent and water, rinsed with tap water, rinsed with distilled water, rinsed with methylene chloride, and air dried at room temperature in a dust-free environment.

Before collection of Type 1 samples, new Tygon® tubing was cut to minimum lengths and installed on the inlet and outlet (suction and discharge) fittings of the automatic sampler. Two liters (2.1 quarts) of blank water, known to be free of organic compounds and brought to the sampling site from the analytical laboratory, were pumped through the sampler and its attached tubing into the glass jug; the water was then distributed to cover the interior of the jug and subsequently discarded.

A blank was produced by pumping an additional 3 liters (0.8 gal) of blank water through the sampler, distributed inside the glass jug, and poured into a 3.8 liter (1 gal) sample bottle that had been cleaned in the same manner as the glass jug. The blank sample was sealed with a Teflon®-lined cap, labeled, and packed in ice in a plastic foam-insulated chest. This sample subsequently was analyzed to determine any contamination contributed by the automatic sampler.

During collection of each Type 1 sample, the glass jug was packed in ice in a separate plastic foam-insulated container. After the complete composite sample had been collected, it was mixed to provide a homogeneous mixture, and two 0.95-liter (1 quart) aliquots were removed for metals analysis and placed in new labeled plastic 0.95-liter bottles which had been rinsed with distilled water. One of these 0.95-liter aliquots was sealed with a Teflon®-lined cap; placed in an iced, insulated chest to maintain it at 4°C (39°F), and shipped by air for plasma-arc metal analysis. Initially, the second sample was stabilized by the addition of 5 ml (0.2 ounce) of concentrated nitric acid, capped and iced in the same manner as the first, and shipped by air to the contractor's facility for atomic-absorption metal analysis.

Because of subsequent EPA notification that the acid pH of the stabilized sample fell outside the limits permissible under Department of Transportation regulations for air shipment, stabilization of the second sample in the field was discontinued. Instead, this sample was acid-stabilized at the analytical laboratory.

After removal of the two 0.95-liter (1 quart) metals aliquots from the composite sample, the balance of the sample in the 11.4-liter (3 gallon) glass jug was subdivided for analysis of nonvolatile organics, asbestos, conventional, and nonconventional parameters. If a portion of this 7.7-liter (2 gallon) sample was requested by a plant representative for independent analysis, a 0.95-liter (1 quart) aliquot was placed in a sample container supplied by the representative.

Sample Types 2 (cyanide) and 3 (total phenol) were stored in new bottles which had been iced and labeled, 1-liter (33.8 ounce) clear plastic bottles for Type 2, and 0.47-liter (16 ounce) amber glass for Type 3. The bottles had been cleaned by rinsing with distilled water, and the samples were preserved as described below.

To each Type 2 (cyanide) sample, sodium hydroxide was added as necessary to elevate the pH to 12 or more (as measured using pH paper). Where the presence of chlorine was suspected, the sample was tested for chlorine (which would decompose most of the cyanide) by using potassium iodide/starch paper. If the paper turned blue, ascorbic acid crystals were slowly added and dissolved until a drop of the sample produced no change in the color of the test paper. An additional 0.6 gram (0.021 ounce) of ascorbic acid was added, and the sample bottle was sealed (by a Teflon®-lined cap), labeled, iced, and shipped for analysis.

To each Type 3 (total phenol) sample, phosphoric acid was added as necessary to reduce the pH to 4 or less (as measured using pH paper). Then, 0.5 gram (0.018 ounce) of copper sulfate was added to kill bacteria, and the sample bottle was sealed (by a Teflon®-lined cap), labeled, iced, and shipped for analysis.

Each Type 4 (volatile organics) sample was stored in a new 125-ml (4.2 ounce) glass bottle that had been rinsed with tap water and distilled water, heated to 105°C (221°F) for one hour, and cooled. This method was also used to prepare the septum and lid for each bottle. Each bottle, when used, was filled to overflowing, sealed with a Teflon®-faced silicone septum (Teflon® side down) and a crimped aluminum cap, labeled, and iced. Hermetic sealing was verified by inverting and tapping the sealed container to confirm the absence of air bubbles. (If bubbles were found, the bottle was opened, a few additional drops of sample were added, and a new seal was installed.) Samples were maintained hermetically sealed and iced until analyzed.

Sample Analysis. Samples were sent by air to contract laboratories. An aliquot of each metal sample received by contract laboratory was sent to EPA's Chicago laboratory for inductively coupled argon plasma emission spectrophotometry (ICAP) analysis; while the contract laboratory retained an aliquot for atomic absorption spectrophotometry (AA). Twenty-two metals were analyzed by ICAP, and five metals were analyzed by AA, as follows:

Metals Analyzed by ICAP

Calcium
Magnesium
Sodium
Silver
Aluminum
Boron
Barium
Beryllium
Cadmium
Cobalt
Chromium
Copper
Iron
Manganese
Molybdenum
Nickel
Lead
Tin
Titanium
Vanadium
Ytrium
Zinc

Metals Analyzed by AA

Antimony
Arsenic
Selenium
Silver
Thallium

Several of these metals analyzed by ICAP are not among the 129 toxic pollutants specified in the settlement agreements. They are considered, however, because they consume lime and increase sludge production in wastewater treatment facilities.

Mercury was analyzed by a special technique: the manual cold vapor flameless atomic adsorption spectrometry technique.

Samples were also analyzed for asbestos by transmission electron microscopy. Total fiber and chrysotile fiber counts were reported by the testing laboratory. Chrysotile was chosen by the Agency as the screening parameter for asbestos for mining related activities because: (1) of its known toxicity when particles are inhaled, (2) its industrial prevalance, (3) its distinguishing selected area electron diffraction (SAED) pattern, and (4) the cumbersome nature of the transmission electron microscopic (TEM) analysis technique limits the identification to one mineral form at the present time due to economics and time constraints.

While the asbestos data vary, the testing laboratory's report indicates that when the total fiber count is performed in conjunction with a count of chrysotile fibers a good initial screening parameter is produced. The report recommends re-examining any facility with chrysotile fiber counts greater than 100 million fibers/liter (MFL) because this represents a significant departure from ambient counts of 3 MFL in the Great Lakes Basin. The technique used had a threshold of detection of 0.22 MFL.

Wastewater samples from the plants sampled in the screening phase were analyzed for asbestos. The verification phase wastewater samples were not analyzed for asbestos.

Verification samples also went to EPA contract laboratories for organics analysis or when metal analysis was performed by AA. Since metals analysis of screening samples was complete before verification metals analysis began, the samples were analyzed only for metals shown to be significant in the nonferrous metals manufacturing category or those expected to consume large amounts of lime.

Due to their very similar physical and chemical properties, it is extremely difficult to separate the seven polychlorinated biphenyls (pollutants 106 to 112) for analytical identification and quantification. For that reason, the concentrations of the polychlorinated biphenyls are reported by the analytical laboratory in two groups: one group consists of PCB-1242, PCB-1254, and PCB-1221; the other group consists of PCB-1232, PCB-1248, PCB-1260, and PCB-1016. For convenience, the first group will be referred to as PCB-1254 and the second as PCB-1248.

The samples were not analyzed for Pollutant 129, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) because no authentic reference sample was available to the analytical laboratory.

Three of the five conventional pollutants parameters were selected for analysis for use in developing BCT and for evaluating treatment system performance. They are total suspended solids (TSS), oil and grease, and pH. The other two conventionals, fecal coliform and biochemical oxygen demand (BOD), were not analyzed because there is no reason to believe that fecal matter or oxygen demanding materials would be present. Ammonia, fluoride, and total phenolics (4-AAP) were analyzed for in selected samples if there was reason to believe they would be present based on the processes used. While not classified as toxic pollutants, they affect the water quality. Chemical oxygen demand (COD) and total organic carbon (TOC) were also selected for analysis for selected samples for subsequent use in evaluating treatment system performance. Total dissolved solids (TDS) was analyzed to evaluate the potential for accumulation of dissolved salts.

In addition, aluminum, calcium, magnesium, alkalinity, total dissolved solids, and sulfate were measured to provide data to evaluate the cost of lime and settle treatment of certain wastewater streams.

The analytical quantification limits used in evaluation of the sampling data reflect the accuracy of the analytical methods used. Below these concentrations, the identification of the individual compounds is possible, but quantification is difficult. Pesticides and PCB's can be analytically quantified at concentrations above 0.005 mg/l, and other organic toxics at concentrations above 0.010 mg/l. Analytical quantification limits associated with toxic metals are as follows: 0.100 mg/l for antimony; 0.10 mg/l for arsenic; 10 MFL for asbestos; 0.010 mg/l for beryllium; 0.002 mg/l for cadmium; 0.005 mg/l for chromium; 0.009 mg/l for copper; 0.100 mg/l for cyanide; 0.02 mg/l for lead; 0.0001 mg/l for mercury; 0.005 mg/l for nickel; 0.010 mg/l for selenium; 0.020 mg/l for silver; 0.100 mg/l for thallium; and 0.050 mg/l for zinc.

These detection limits are not the same as published detection limits for these pollutants by the same analytical methods (40 CFR Part 136 - Guidelines Establishing Test Procedures for the Analysis of Pollutants; 40 CFR Part 136 - Proposed, 44 FR 69464, December 3, 1979; 1982 Annual Book of ASTM Standards, Part 31, Water, ASTM, Philadelphia, PA; Methods for Chemical Analysis of Water and Wastes, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. EPA Cincinnati, OH, March, 1979, EPA-600 4-79-020; Handbook for Monitoring Industrial Wastewater, U.S. EPA Technology Transfer, August, 1973). The detection limits used were reported with the analytical data and hence are the appropriate limits to apply to the data. Detection limit variation can occur as a result of a number of laboratory-specific, equipment-specific, and daily operator-specific factors. These factors can include day-to-day differences in machine calibration, variation in stock solutions, and variation in operators.

Quality Control. Quality control measures used in performing all analyses conducted for this program complied with the guidelines given in "Handbook for Analytical Quality Control in Water and Wastewater Laboratories" (published by EPA Environmental Monitoring and Support Laboratory, Cincinnati, Ohio, 1976). As part of the daily quality control program, blanks (including sealed samples of blank water carried to each sampling site and returned unopened, as well as samples of blank water used in the field), standards, and spiked samples were routinely analyzed with actual samples. As part of the overall program, all analytical instruments (such as balances, spectrophotometers, and recorders) were routinely maintained and calibrated.

The atomic-absorption spectrometer used for metal analysis was checked to see that it was operating correctly and performing within expected limits. Appropriate standards were included after at least every 10 samples. Also, approximately 15 percent of the analyses were spiked with distilled water to assure recovery of the metal of interest. Reagent blanks were analyzed for each metal, and sample values were corrected if necessary.

WATER USE AND WASTEWATER CHARACTERISTICS

In each of the subcategory supplements, wastewater characteristics corresponding to the subcategories in the nonferrous metals manufacturing category are presented and discussed. Tables are presented in Section V of each of the subcategory supplements which present the sampling program data for raw waste and treated effluent sampled streams. For those pollutants detected above analytically quantifiable concentrations in any sample of a given wastewater stream, the actual analytical data is presented. Where no data is listed for a specific day of sampling, it indicates that the wastewater samples for the stream were not collected.

The statistical analysis of data includes some samples measured at concentrations considered not quantifiable. The base neutrals, acid fraction, and volatile organics are considered not quantifiable at concentrations equal to or less than 0.010 mg/l. Below this level, organic analytical results are not quantitatively accurate; however, the analyses are useful to indicate the presence of a particular pollutant. Nonquantifiable results are designated in the tables with an asterisk (double asterisk for pesticides).

When calculating averages from the organic sample data, nonquantifiable results were assumed to be zero. Organics data reported as not detected (ND) are not averaged. For example, three samples reported as ND, *, 0.021 mg/l would average as 0.010 mg/l.

Table V-1

DISTRIBUTION OF SAMPLED PLANTS IN THE NONFERROUS METALS MANUFACTURING CATEGORY BY SUBCATEGORY

Subcategory	Total Number of Plants Sampled	Number of Plants Sampled by Other Contractors or EPA Regions	Number of Plants Screened Sampled	Number of Plants Verification Sampled
Primary Aluminum	6	2	1	3
Secondary Aluminum	5	-	1	4
Primary Copper	4	2	-	2
Secondary Copper	5	-	2	3
Primary Lead	3	3	-	-
Secondary Lead	6	1	1	4
Primary Zinc	5	2	2	1
Primary Tungsten	4	-	1	3
Primary Columbium-Tantalum	4	-	1	3
Secondary Silver	4	-	1	3
Metallurgical Acid Plants*	-	-	-	-
TOTAL	46	10	10	26

*Acid plant wastewater samples were collected at the primary copper, lead, and zinc plants listed above.

Section VI

SELECTION OF POLLUTANT PARAMETERS

The Agency has studied nonferrous metals manufacturing wastewaters to determine the presence or absence of toxic, conventional and selected nonconventional pollutants. The toxic pollutants and nonconventional pollutants are subject to BAT effluent limitations and guidelines. Conventional pollutants are considered in establishing BPT, BCT, and NSPS limitations.

One hundred and twenty-nine toxic pollutants (known as the 129 priority pollutants) were studied pursuant to the requirements of the Clean Water Act of 1977 (CWA). These pollutant parameters, which are listed in Table VI-1, are members of the 65 pollutants and classes of toxic pollutants referred to in Section 307(a)(1) of the CWA.

From the original list of 129 pollutants, three pollutants have been deleted in two separate amendments to 40 CFR Subchapter N, Part 401. Dichlorodifluoromethane and trichlorofluoromethane were deleted first (46 FR 2266, January 8, 1981) followed by the deletion of bis-(chloromethyl) ether (46 FR 10723, February 4, 1981). The Agency has concluded that deleting these compounds will not compromise adequate control over their discharge into the aquatic environment and that no adverse effects on the aquatic environment or on human health will occur as a result of deleting them from the list of toxic pollutants.

Past studies by EPA and others have identified many nontoxic pollutant parameters useful in characterizing industrial wastewaters and in evaluating treatment process removal efficiencies. For this reason, a number of nontoxic pollutants were also studied for the nonferrous metals manufacturing category.

EPA has defined the criteria for the selection of conventional pollutants (43 FR 32857 January 11, 1980). These criteria are:

1. Generally those pollutants that are naturally occurring, biodegradable; oxygen-demanding materials, and solids that have characteristics similar to naturally occuring, biodegradable substances; or,

2. Include those classes of pollutants that traditionally have been the primary focus of wastewater control.

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The conventional pollutants considered in this rulemaking (total suspended solids, oil and grease, and pH) traditionally have been studied to characterize industrial wastewaters. These parameters impact water quality and are especially useful in evaluating the effectiveness of some wastewater treatment processes.

Several nonconventional pollutants were also considered in developing these regulations. These included aluminum, chemical oxygen demand (COD), and total organic carbon (TOC). In addition, calcium, magnesium, alkalinity, total dissolved solids and sulfate were measured to provide data to evaluate the cost of chemical precipitation and sedimentation treatment of certain wastewater streams.

Fluoride, ammonia (NH_3) and total phenolics (4-AAP) were also identified as pollutants for some of the subcategories. Fluoride compounds are used in the production of primary aluminum and columbium-tantalum and are present in the raw wastewater of these industries. In the primary and secondary aluminum, secondary lead, secondary silver, primary columbium-tantalum, and primary tungsten subcategories, NH_3 is used in the process or formed during a process step. In other subcategories, it has been used for neutralization of the wastewater.

RATIONALE FOR SELECTION OF POLLUTANT PARAMETERS

In determining which pollutants to regulate, a pollutant that was never detected, or that was never found above its analytical quantification level, was eliminated from consideration. The analytical quantification level for a pollutant is the minimum concentration at which that pollutant can be reliably measured. Below that concentration, the identification of the individual compounds is possible, but quantification is difficult. For the toxic pollutants in this study, the analytical quantification levels are: 0.005 mg/l for pesticides, PCB's, chromium, and nickel; 0.010 mg/l for the remaining organic toxic pollutants and cyanide, arsenic, beryllium, and selenium; 10 million fibers per liter (10 MFL) for asbestos; 0.020 mg/l for lead and silver; 0.009 mg/l for copper; 0.002 mg/l for cadmium; and 0.0001 mg/l for mercury.

These detection limits are not the same as published detection limits for these pollutants by the same analytical methods. The detection limits used were reported with the analytical data and hence are the appropriate limits to apply to the data. Detection limit variation can occur as a result of a number of laboratory-specific, equipment-specific, and daily operator-specific factors. These factors can include day-to-day differences in machine calibration, variation in stock solutions, and variation in operators.

Because the analytical standard for TCDD was judged to be too hazardous to be made generally available, samples were never analyzed for this pollutant. There is no reason to expect that TCDD would be present in nonferrous metals manufacturing wastewaters.

Pollutants which were detected below concentrations considered achievable by available treatment technology were also eliminated from further consideration. For the toxic metals, the chemical precipitation, sedimentation, and filtration technology treatability values, which are presented in Section VII (Table VII-22) were used. For the toxic organic pollutants detected above their analytical quantification limit, achievable concentrations for activated carbon technology were used. These concentrations represent the most stringent treatment options considered for pollutant removal.

The pollutant exclusion procedure was applied to the raw waste data for each subcategory. Detailed specific results are presented in Section VI of each of the subcategory supplements. Summary results of selected pollutants for each subcategory are presented later in this section.

Toxic pollutants remaining after the application of the exclusion process were then selected for further consideration in establishing specific regulations.

DESCRIPTION OF POLLUTANT PARAMETERS

The following discussion addresses the pollutant parameters detected above their analytical quantification limit in any sample of nonferrous metals manufacturing wastewater. The description of each pollutant provides the following information: the source of the pollutant; whether it is a naturally occuring element, processed metal, or manufactured compound; general physical properties and the form of the pollutant; toxic effects of the pollutant in humans and other animals; and behavior of the pollutant in a POTW at concentrations that might be expected from industrial discharges.

Acenaphthene (1). Acenaphthene (1,2-dihydroacenaphthylene, or 1,8-ethylene-naphthalene) is a polynuclear aromatic hydrocarbon (PAH) with molecular weight of 154 and a formula of $C_{12}H_{10}$.

Acenaphthene occurs in coal tar produced during high temperature coking of coal. It has been detected in cigarette smoke and gasoline exhaust condensates.

The pure compound is a white crystalline solid at room temperature with a melting range of 95°C to 97°C and a boiling range of 278°C to 280°C. Its vapor pressure at room temperature is less than 0.02 mm Hg. Acenaphthene is slightly soluble in water (100 mg/l), but even more soluble in organic solvents such as ethanol, toluene, and chloroform. Acenaphthene can be oxidized by oxygen or ozone in the presence of certain catalysts. It is stable under laboratory conditions.

Acenaphthene is used as a dye intermediate, in the manufacture of some plastics, and as an insecticide and fungicide.

So little research has been performed on acenaphthene that its mammalian and human health effects are virtually unknown. The water quality criterion of 0.02 mg/l is recommended to prevent the adverse effects on humans due to the organoleptic properties of acenaphthene in water.

No detailed study of acenaphthene behavior in a POTW is available. However, it has been demonstratd that none of the organic toxic pollutants studied so far can be broken down by biological treatment processes as readily as fatty acids, carbohydrates, or proteins. Many of the toxic pollutants have been investigated, at least in laboratory-scale studies, at concentrations higher than those expected to be contained by most municipal wastewaters. General observations relating molecular structure to ease of degradation have been developed for all of the toxic organic pollutants.

The conclusion reached by study of the limited data is that biological treatment produces little or no degradation of acenaphthene. No evidence is available for drawing conclusions about its possible toxic or inhibitory effect on POTW operation.

Its water solubility would allow acenaphthene present in the influent to pass through a POTW into the effluent. The hydrocarbon character of this compound makes it sufficiently hydrophobic that adsorption onto suspended solids and retention in the sludge may also be a significant route for removal of acenaphthene from the POTW.

Acenaphthene has been demonstrated to affect the growth of plants through improper nuclear division and polyploidal chromosome number. However, it is not expected that land application of sewage sludge containing acenaphthene at the low concentrations which are to be expectd in a POTW sludge would result in any adverse effects on animals ingesting plants grown in such soil.

Benzene (4). Benzene (C_6H_6) is a clear, colorless liquid obtained mainly from petroleum feedstocks by several different processes. Some is recovered from light oil obtained from coal carbonization gases. It boils at 80°C and has a vapor pressure of 100 mm Hg at 26°C. It is slightly soluble in water (1.8 g/l at 25°C) and it dissolves in hydrocarbon solvents. Annual U.S. production is three to four million tons.

Most of the benzene used in the U.S. goes into chemical manufacture. About half of that is converted to ethylbenzene which is used to make styrene. Some benzene is used in motor fuels.

Benzene is harmful to human health according to numerous published studies. Most studies relate effects of inhaled benzene vapors. These effects include nausea, loss of muscle coordination, and excitement, followed by depression and coma. Death is usually the result of respiratory or cardiac failure. Two specific blood disorders are related to benzene exposure. One of these, acute myelogenous leukemia, represents a carcinogenic effect of benzene. However, most human exposure data is based on exposure in occupational settings and benzene carcinogenisis is not considered to be firmly established.

Oral administration of benzene to laboratory animals produced leukopenia, a reduction in mumber of leukocytes in the blood. Subcutaneous injection of benzene-oil solutions has produced suggestive, but not conclusive, evidence of benzene carcinogenisis.

Benzene demonstrated teratogenic effects in laboratory animals, and mutagenic effects in humans and other animals.

For maximum protection of human health from the potential carcinogenic effects of exposure to benzene through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of benzene estimated to result in additional lifetime cancer risk at levels of 10^{-7}, 10^{-6}, and 10^{-5} are 0.15 ug/l, 1.5 ug/l, and 15 ug/l, respectively.

Some studies have been reported regarding the behavior of benzene in a POTW. Biochemical oxidation of benzene under laboratory conditions, at concentrations of 3 to 10 mg/l, produced 24, 27, 24, and 20 percent degradation in 5, 10, 15, and 20 days, respectively, using unacclimated seed cultures in fresh water. Degradation of 58, 67, 76, and 80 percent was produced in the same time periods using acclimated seed cultures. Other studies produced similar results. Based on these data and general conclusions relating molecular structure to biochemical oxidation, it is expected that biological treatment in a POTW will remove benzene readily from the water. Other reports indicate that most benzene entering a POTW is removed to the sludge and that influent concentrations of 1 g/l inhibit sludge digestion. There is no information about possible effects of benzene on crops grown in soils amended with sludge containing benzene.

Carbon Tetrachloride (6). Carbon tetrachloride (CCl_4), also called tetrachloromethane, is a colorless liquid produced primarily by the chlorination of hydrocarbons - particularly methane. Carbon tetrachloride boils at 77°C and has a vapor pressure of 90 mm Hg at 20°C. It is slightly soluble in water (0.8 gm/l at 25°C) and soluble in many organic solvents. Approximately one-third of a million tons is produced annually in the U.S.

Carbon tetrachloride, which was displaced by perchloroethylene as a dry cleaning agent in the 1930's, is used principally as an intermediate for production of chlorofluoromethanes for refrigerants, aerosols, and blowing agents. It is also used as a grain fumigant.

Carbon tetrachloride produces a variety of toxic effects in humans. Ingestion of relatively large quantities - greater than five grams - has frequently proved fatal. Symptoms are burning sensation in the mouth, esophagus, and stomach, followed by abdominal pains, nausea, diarrhea, dizziness, abnormal pulse, and coma. When death does not occur immediately, liver and kidney damage are usually found. Symptoms of chronic poisoning are not as well defined. General fatigue, headache, and anxiety have been observed, accompanied by digestive tract and kidney discomfort or pain.

Data concerning teratogenicity and mutagenicity of carbon tetrachloride are scarce and inconclusive. However, carbon tetrachloride has been demonstrated to be carcinogenic in laboratory animals. The liver was the target organ.

For maximum protection of human health from the potential carcinogenic effects of exposure to carbon tetrachloride through ingestion of water and contaminated aquatic organisms, the ambient water concentration of zero. Concentrations of carbon tetrachloride estimated to result in additional lifetime cancer risk at risk levels of 10^{-7}, 10^{-6}, and 10^{-5} are 0.026 ug/l, 0.26 ug/l, and 2.6 ug/l, respectively.

Data on the behavior of carbon tetrachloride in a POTW are not available. Many of the toxic organic pollutants have been investigated, at least in laboratory-scale studies, at concentrations higher than those expected to be found in most municipal wastewaters. General observations have been developed relating molecular structure to ease of degradation for all of the toxic organic pollutants. The conclusion reached by study of the limited data is that biological treatment produces a moderate degree of removal of carbon tetrachloride in a POTW. No information was found regarding the possible interference of carbon tetrachloride with treatment processes. Based on the water solubility of carbon tetrachloride, and the vapor pressure of this compound, it is expected that some of the undegraded carbon tetrachloride will pass through to the POTW effluent and some will be volatilized in aerobic processes.

Chlorobenzene (7). Chlorobenzene (C_6H_5Cl), also called monochlorobenzene is a clear, colorless, liquid manufactured by the liquid phase chlorination of benzene over a catalyst. It boils at 132°C and has a vapor pressure of 12.5 mm Hg at 25°C. It is almost insoluble in water (0.5 g/l at 30°C), but dissolves in hydrocarbon solvents. U.S. annual production is near 150,000 tons.

Principal uses of chlorobenzene are as a solvent and as an intermediate for dyes and pesticides. Formerly it was used as an intermediate for DDT production, but elimination of production of that compound reduced annual U.S. production requirements for chlorobenzene by half.

Data on the threat to human health posed by chlorobenzene are limited in number. Laboratory animals, administered large doses of chlorobenzene subcutaneously, died as a result of central nervous system depression. At slightly lower dose rates, animals died of liver or kidney damage. Metabolic disturbances occurred also. At even lower dose rates of orally administered chlorobenzene similar effects were observed, but some animals survived longer than at higher dose rates. No studies have been reported regarding evaluation of the teratogenic, mutagenic, or carcinogenic potential of chlorobenzene.

For the prevention of adverse effects due to the organoleptic properties of chlorobenzene in water the recommended criterion is 0.020 mg/l.

Only limited data are available on which to base conclusions about the behavior of chlorobenzene in a POTW. Laboratory studies of the biochemical oxidation of chlorobenzene have been carried out at concentrations greater than those expected to normally be present in POTW influent. Results showed the extent of degradation to be 25, 28, and 44 percent after 5, 10, and 20 days, respectively. In another, similar study using a phenol-adapted culture 4 percent degradation was observed after 3 hours with a solution containing 80 mg/l. On the basis of these results and general conclusions about the relationship of molecular structure to biochemical oxidation, it is concluded that chlorobenzene remaining intact is expected to volatilize from the POTW in aeration processes. The estimated half-life of chlorobenzene in water based on water solubility, vapor pressure and molecular weight is 5.8 hours.

1,2,4-Trichlorobenzene (8). 1,2,4-Trichlorobenzene ($C_6H_3Cl_3$), 1,2,4-TCB) is a liquid at room temperature, solidifying to a crystalline solid at 17°C and boiling at 214°C. It is produced by liquid phase chlorination of benzene in the presence of a catalyst. Its vapor pressure is 4 mm Hg at 25°C. 1,2,4-TCB is insoluble in water and soluble in organic solvents. Annual U.S. production is in the range of 15,000 tons. 1,2,4-TCB is used in limited quantities as a solvent and as a dye carrier in the textile industry. It is also used as a heat transfer medium and as a transfer fluid. The compound can be selectively chlorinated to 1,2,4,5-tetrachlorobenzene using iodine plus antimony trichloride as catalyst.

No reports were available regarding the toxic effects of 1,2,4-TCB on humans. Limited data from studies of effects in laboratory animals fed 1,2,4-TCB indicate depression of activity at low doses and predeath extension convulsions at lethal doses. Metabolic disturbances and liver changes were also observed. Studies for the purpose of determining teratogenic or mutagenic properties of 1,2,4-TCB have not been conducted. No studies have been made of carcinogenic behavior of 1,2,4-TCB administered orally.

For the prevention of adverse effects due to the organoleptic properties of 1,2,4-trichlorobenzene in water, the water quality criterion is 0.013 mg/l.

Data on the behavior of 1,2,4-TCB in POTW are not available. However, this compund has been investigated in a laboratory scale study of biochemical oxidation at concentrations higher than those expected to be contained by most municipal wastewaters. Degradations of 0, 87, and 100 percent were observed after 5, 10, and 20 days, respectively. Using this observation and general observations relating molecular structure to ease of degradation for all of the organic priority pollutants, the conclusion was reached that biological treatment produces a high degree of removal in POTW.

1,2-Dichloroethane (10). 1,2-Dichloroethane is a halogenated aliphatic used in the production of tetraethyl lead and vinyl chloride, as an industrial solvent, and as an intermeidate in the production of other organochlorine compounds. Some chlorinated ethanes have been found in drinking waters, natural waters, aquatic organisms and foodstuffs. Research indicates that they may have mutagenic and carcinogenic properties.

1,1,1-Trichloroethane (11). 1,1,1-Trichloroethane is one of the two possible trichlorethanes. It is manufactured by hydrochlorinating vinyl chloride to 1,1-dichloroethane which is then chlorinated to the desired product. 1,1,1-Trichloroethane is a liquid at room temperature with a vapor pressure of 96 mm Hg at 20°C and a boiling point of 74°C. Its formula is CCl_3CH_3. It is slightly soluble in water (0.48 g/l) and is very soluble in organic solvents. U.S. annual production is greater than one-third of a million tons

1,1,1-Trichloroethane is used as an industrial solvent and degreasing agent.

Most human toxicity data for 1,1,1-trichloroethane relates to inhalation and dermal exposure routes. Limited data are available for determining toxicity of ingested 1,1,1-trichloroethane, and those data are all for the compound itself, not solutions in water. No data are available regarding its toxicity to fish and aquatic organisms. For the protection of human health from the toxic properties of 1,1,1-trichloroethane ingested through the comsumption of water and fish, the ambient water criterion is 15.7 mg/l. The criterion is based on bioassays for possible carcinogenicity.

No detailed study of 1,1,1-trichloroethane behavior in a POTW is available. However, it has been demonstrated that none of the toxic organic pollutants of this type can be broken down by biological treatment processes as readily as fatty acids, carbohydrates, or proteins.

Biochemical oxidation of many of the toxic organic pollutants has been investigated, at least in laboratory scale studies, at concentrations higher than commonly expected in municipal wastewater. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by study of the limited data is that biological treatment produces a moderate degree of degradation of 1,1,1-trichloroethane. No evidence is available for drawing conclusions about its possible toxic or inhibitory effect on POTW operation. However, for degradation to occur, a fairly constant input of the compound would be necessary.

Its water solubility would allow 1,1,1-trichloroethane, present in the influent and not biodegradable, to pass through a POTW into the effluent. One factor which has received some attention, but no detailed study, is the volatilization of the lower molecular weight organics from a POTW. If 1,1,1-trichloroethane is not biodegraded, it will volatilize during aeration processes in the POTW.

Hexachloroethane (12). Hexachloroethane (CCl_3CCl_3), also called perchloroethane is a white crystalline solid with a camphor-like odor. It is manufactured from tetrachloroethylene, and is a minor product in many industrial chlorination processes designed to produce lower chlorinated hydrocarbons. Hexachloroethane sublimes at 185°C and has a vapor pressure of about 0.2 mm Hg at 20°C. It is insoluble in water (50 mg/l at 22°C) and soluble in some organic solvents.

Hexachloroethane can be used in lubricants designed to withstand extreme pressure. It is used as a plasticizer for cellulose esters, and as a pesticide. It is also used as a retarding agent in fermentation, as an accelerator in the rubber industry, and in pyrotechnic and smoke devices.

Hexachloroethane is considered to be toxic to humans by ingestion and inhalation. In laboratory animals liver and kidney damage have been observed. Symptoms in humans exposed to hexachloroethane vapor include severe eye irritation and vision impairment. Based on studies on laboratory animals, hexachloroethane is considered to be carcinogenic.

For the maximum protection of human health from the potential carcinogenic effects of exposure to hexachloroethane through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of hexachloroethane estimated to result in additional lifetime cancer risks at levels of 10^{-7}, 10^{-6}, and 10^{-5} are 0.059 ug/l, 0.59 ug/l, and 5.9 ug/l, respectively.

Data on the behavior of hexachloroethane in POTW are not available. Many of the organic priority pollutants have been investigated, at least in laboratory scale studies, at concentrations higher than those expected to be contained by most municipal wastewaters. General observations have been developed relating molecular structure to ease of degradation for all of the organic priority pollutants. The conclusion reached by study of the limited data is that biological treatment produces little or no removal of hexachloroethane in POTW. The lack of water solubility and the expected affinity of hexachloroethane for solid particles lead to the expectation that this compound will be removed to the sludge in POTW. No information was found regarding possible uptake of hexachloroethane by plants grown on soils amended with hexachloroethane-bearing sludge.

1,1-Dichloroethane (13). 1,1-Dichloroethane, also called ethylidene dichloride and ethylidene chloride, is a colorless liquid manufactured by reacting hydrogen chloride with vinyl chloride in 1,1-dichloroethane solution in the presence of a catalyst. However, it is reportedly not manufactured commercially in the U.S. 1,1-Dichloroethane boils at 57°C and has a vapor pressure of 182 mm Hg at 20°C. It is slightly soluble in water (5.5 g/l at 20°C) and very soluble in organic solvents.

1,1-Dichloroethane is used as an extractant for heat-sensitive substances and as a solvent for rubber and silicone grease.

1,1-Dichloroethane is less toxic than its isomer (1,2-dichloroethane), but its use as an anesthetic has been discontinued because of marked excitation of the heart. It causes central nervous system depression in humans. There are insufficient data to derive water quality criteria for 1,1-dichloroethane.

Data on the behavior of 1,1-dichloroethane in a POTW are not available. Many of the toxic organic pollutants have been investigated, at least in laboratory scale studies, at concentrations higher than those expected to be contained by most municipal wastewaters. General observations have been developed relating molecular structure to ease of degradation for all of the toxic organic pollutants. The conclusion reached by study of the limited data is that biological treatment produces only a moderate removal of 1,1-dichloroethane in a POTW by degradation.

The high vapor pressure of 1,1-dichloroethane is expected to result in volatilization of some of the compound from aerobic processes in a POTW. Its water solubility will result in some of the 1,1-dichloroethane which enters the POTW leaving in the effluent from the POTW.

1,1,2-Trichloroethane (14). 1,1,2-Trichloroethane is one of the two possible trichloroethanes and is sometimes called ethane trichloride or vinyl trichloride. It is used as a solvent for fats, oils, waxes, and resins, in the manufacture of 1,1-dichloroethylene, and as an intermediate in organic synthesis.

1,1,2-Trichloroethane is a clear, colorless liquid at room temperature with a vapor pressure of 16.7 mm Hg at 20°C, and a boiling point of 113°C. It is insoluble in water and very soluble in organic solvents. The formula is $CHCl_2CH_2Cl$.

Human toxicity data for 1,1,2-trichloroethane does not appear in the literature. The compound does produce liver and kidney damage in laboratory animals after intraperitoneal administration. No literature data was found concerning teratogenicity or mutagenicity of 1,1,2-trichloroethane. However, mice treated with 1,1,2-trichloroethane showed increased incidence of hepatocellular carcinoma. Although bioconcentration factors are not available for 1,1,2-trichloroethane in fish and other freshwater aquatic organisms, it is concluded on the basis of octanol-water partition coefficients that bioconcentration does occur.

For the maximum protection of human health from the potential carcinogenic effects of exposure to 1,1,2-trichloroethane through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of this compound estimated to result in additional lifetime cancer risks at risk levels of 10^{-7}, 10^{-6}, and 10^{-5} are 0.06 ug/l, 0.6 ug/l, and 6 ug/l, respectively. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the water concentration should be less than 0.418 mg/l to keep the increased lifetime cancer risk below 10^{-5}. Available data show that adverse effects on aquatic life occur at concentrations higher than those cited for human health risks.

No detailed study of 1,1,2-trichloroethane behavior in a POTW is available. However, it is reported that small amounts are formed by chlorination processes and that this compound persists in the environment (greater than two years) and it is not biologically degraded. This information is not completely consistant with the conclusions based on laboratory scale biochemical oxidation studies and relating molecular structure to ease of degradation. That study concluded that biological treatment in a POTW will produce moderate removal of 1,1,2-trichloroethane.

The lack of water solubility and the relatively high vapor pressure may lead to removal of this compound from a POTW by volatilization.

2,4,6-Trichlorophenol (21). 2,4,6-Trichlorophenol ($Cl_3C_6H_2OH$, abbreviated here to 2,4,6-TCP) is a colorless, crystalline solid at room temperature. It is prepared by the direct chlorination of phenol. 2,4,6-TCP melts at 68°C and is slightly soluble in water (0.8 gm/l at 25°C). This phenol does not produce a color with 4-aminoantipyrene, and therefore does not contribute to the nonconventional pollutant parameter "Total Phenols." No data were found on production volumes.

2,4,6-TCP is used as a fungicide, bactericide, glue and wood preservative, and for antimildew treatment. It is also used for the manufacture of 2,3,4,6-tetrachlorophenol and pentachlorophenol.

No data were found on human toxicity effects of 2,4,6-TCP. Reports of studies with laboratory animals indicate that 2,4,6-TCP produced convulsions when injected interperitoneally. Body temperature was elevated also. The compound also produced inhibition of ATP production in isolated rat liver mitochondria, increased mutation rates in one strain of bacteria, and produced a genetic change in rats. No studies on teratogenicity were found. Results of a test for carcinogenicity were inconclusive.

For the prevention of adverse effects due to the organoleptic properties of 2,4,6-trichlorophenol in water, the water quality criterion is 0.100 mg/l.

Although no data were found regarding the behavior of 2,4,6-TCP in a POTW, studies of the biochemical oxidation of the compound have been made at laboratory scale at concentrations higher than those normally expected in municipal wastewaters. Biochemical oxidation of 2,4,6-TCP at 100 mg/l produced 23 percent degradation using a phenol-adapted acclimated seed culture. Based on these results, biological treatment in a POTW is expected to produce a moderate degree of degradation. Another study indicates that 2,4,6-TCP may be produced in a POTW by chlorination of phenol during normal chlorination treatment.

Para-chloro-meta-cresol (22). Para-chloro-meta-cresol (ClC_7H_6OH) is thought to be a 4-chloro-3-methyl-phenol (4-chloro-meta-cresol, or 2-chloro-5-hydroxy-toluene), but is also used by some authorities to refer to 6-chloro-3-methyl-phenol (6-chloro-meta-cresol, or 4-chloro-3-hydroxy-toluene), depending on whether the chlorine is considered to be para to the methyl or to the hydroxy group. It is assumed for the purposes of this document that the subject compound is 2-chloro-5-hydroxy-toluene. This compound is a colorless crystalline solid melting at 66 to 68°C. It is slightly soluble in water (3.8 gm/l) and soluble in organic solvents. This phenol reacts with 4-amino-antipyrene to give a colored product and therefore contributes to the nonconventional pollutant parameter designated "Total Phenols." No information on manufacturing methods or volumes produced was found.

Para-chloro-meta cresol (abbreviated here as PCMC) is marketed as a microbicide, and was proposed as an antiseptic and disinfectant more than 40 years ago. It is used in glues, gums, paints, inks, textiles, and leather goods. PCMC was found in raw wastewaters from the die casting quench operation from one subcategory of foundry operations.

Although no human toxicity data are available for PCMC, studies on laboratory animals have demonstrated that this compound is toxic when administered subcutaneously and intravenously. Death was preceded by severe muscle tremors. At high dosages kidney damage occurred. On the other hand, an unspecified isomer of chlorocresol, presumed to be PCMC, is used at a concentration of 0.15 percent to preserve muicous heparin, a natural product administered intravenously as an anticoagulant. The report does not indicate the total amount of PCMC typically received. No information was found regarding possible teratogenicity, or carcinogenicity of PCMC.

Two reports indicate that PCMC undergoes degradation in biochemical oxidation treatments carried out at concentrations higher than are expected to be encountered in POTW influents. One study showed 50 percent degradation in 3.5 hours when a phenol-adapted acclimated seed culture was used with a solution of 60 mg/l PCMC. The other study showed 100 percent degradation of a 20 mg/l solution of PCMC in two weeks in an aerobic activated sludge test system. No degradation of PCMC occurred under anaerobic conditions.

Chloroform (23). Chloroform also called trichloromethane, is a colorless liquid manufactured commercially by chlorination of methane. Careful control of conditions maximizes chloroform production, but other products must be separated. Chloroform boils at 61°C and has a vapor pressure of 200 mm Hg at 25°C. It is slightly soluble in water (8.22 g/l at 20°C) and readily soluble in organic solvents.

Chloroform is used as a solvent and to manufacture refrigerants, pharmaceuticals, plastics, and anesthetics. It is seldom used as an anesthetic.

Toxic effects of chloroform on humans include central nervous system depression, gastrointestinal irritation, liver and kidney damage and possible cardiac sensitization to adrenalin. Carcinogenicity has been demonstrated for chloroform on laboratory animals.

For the maximum protection of human health from the potential carcinogenic effects of exposure to chloroform through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of chloroform estimated to result in additional lifetime cancer risks at the levels of 10^{-7}, 10^{-6}, and 10^{-5} were 0.021 ug/l, 0.21 ug/l, and 2.1 ug/l, respectively.

No data are available regarding the behavior of chloroform in a POTW. However, the biochemical oxidation of this compound was studied in one laboratory scale study at concentrations higher than those expected to be contained by most municipal wastewaters. After 5, 10, and 20 days no degradation of chloroform was observed. The conclusion reached is that biological treatment produces little or no removal by degradation of chloroform in a POTW.

The high vapor pressure of chloroform is expected to result in volatilization of the compound from aerobic treatment steps in a POTW. Remaining chloroform is expected to pass through into the POTW effluent.

2-Chlorophenol (24). 2-Chlorophenol (ClC_6H_4OH), also called ortho-chlorophenol, is a colorless liquid at room temperature, manufactured by direct chlorination of phenol followed by distillation to separate it from the other principal product, 4-chlorophenol. 2-Chlorophenol solidifies below 7°C and boils at 176°C. It is soluble in water (28.5 gm/l at 20°C) and soluble in several types of organic solvents. This phenol gives a strong color with 4-aminoantipyrene and therefore contributes to the nonconventional pollutant parameter "Total Phenols." Production statistics could not be found. 2-Chlorophenol is used almost exclusively as a chemical intermediate in the production of pesticides and dyes. Production of some phenolic resins uses 2-chlorophenol.

Very few data are available on which to determine the toxic effects of 2-chlorophenol on humans. The compound is more toxic to laboratory mammals when administered orally than when administered subcutaneously or intravenously. This affect is attributed to the fact that the compound is almost completely in the un-ionized state at the low pH of the stomach and hence is more readily absorbed into the body. Initial symptoms are restlessness and increased respiration rate, followed by motor weakness and convulsions induced by noise or touch. Coma follows. Following lethal doses, kidney, liver, and intestinal damage were observed. No studies were found which addressed the teratogenicity or mutagenicity of 2-chlorophenol. Studies of 2-chlorophenol as a promoter of carcinogenic activity of other carcinogens were conducted by dermal application. Results do not bear a determinable relationship to results of oral administration studies.

For the prevention of adverse effects due to the organoleptic properties of 2-chlorophenol in water, the criterion is 0.0003 mg/l.

Data on the behavior of 2-chlorophenol in a POTW are not available. However, laboratory scale studies have been conducted at concentrations higher than those expected to be found in municipal wastewaters. At 1 mg/l of 2-chlorophenol, an acclimated culture produced 100 percent degradation by biochemical oxidation after 15 days. Another study showed 45, 70, and 79 percent degradation by biochemical oxidation after 5, 10, and 20 days, respectively. The conclusion reached by the study of these limited data, and general observations on all toxic organic pollutants relating molecular structure to ease of biochemcial oxidation, is that 2-chlorophenol is removed to a high degree or completely by biological treatment in a POTW. Undegraded 2-chlorophenol is expected to pass through a POTW into the effluent because of the water solubility. Some 2-chlorophenol is also expected to be generated by chlorination treatments of POTW effluents containing phenol.

1,1-Dichloroethylene (29). 1,1-Dichloroethylene (1,1-DCE), also called vinylidene chloride, is a clear colorless liquid manufactured by dehydrochlorination of 1,1,2-trichloroethane. 1,1-DCE has the formula CCl_2CH_2. It has a boiling point of 32°C, and a vapor pressure of 591 mm Hg at 25°C. 1,1-DCE is slightly soluble in water (2.5 mg/l) and is soluble in many organic solvents. U.S. production is in the range of hundreds of thousands of tons annually.

1,1-DCE is used as a chemical intermediate and for copolymer coatings or films. It may enter the wastewater of an industrial facility as the result of decomposition of 1,1,1-trichloroethylene used in degreasing operations, or by migration from vinylidene chloride copolymers exposed to the process water. Human toxicity of 1,1-DCE has not been demonstrated; however, it is a suspected human carcinogen. Mammalian toxicity studies have focused on the liver and kidney damage produced by 1,1-DCE. Various changes occur in those organs in rats and mice ingesting 1,1-DCE.

For the maximum protection of human health from the potential carcinogenic effects of exposure to 1,1-dichloroethylene through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. The concentration of 1,1-DCE estimated to result in an additional lifetime cancer risk of 1 in 100,000 is 0.0013 mg/l.

Under laboratory conditions, dichloroethylenes have been shown to be toxic to fish. The primary effect of acute toxicity of the dichloroethylenes is depression of the central nervous system. The octanol/water partition coefficident of 1,1-DCE indicates it should not accumulate significantly in animals.

The behavior of 1,1-DCE in a POTW has not been studied. However, its very high vapor pressure is expected to result in release of significant percentages of this material to the atmosphere in any treatment involving aeration. Degradation of dichloroethylene in air is reported to occur, with a half-life of eight weeks.

Biochemical oxidation of many of the toxic organic pollutants has been investigated in laboratory scale studies at concentrations higher than would normally be expected in municipal wastewaters. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by study of the limited data is that biological treatment produces little or no degradation of 1,1-dichloroethylene. No evidence is available for drawing conclusions about the possible toxic or inhibitory effect of 1,1-DCE on POTW operation. Because of water solubility, 1,1-DCE which is not volatilized or degraded is expected to pass through a POTW. Very little 1,1-DCE is expected to be found in sludge from a POTW.

1,2-trans-Dichloroethylene (30). 1,2-Dichloroethylene (1,2-trans-DCE) is a clear, colorless liquid with the formula CHClCHCl. 1,2-*trans*-DCE is produced in mixture with the *cis*-isomer by chlorination of acetylene. The *cis*-isomer has distinctly different physical properties. Industrially, the mixture is used rather than the separate isomers. 1,2-*trans*-DCE has a boiling point of 48°C, and a vapor pressure of 234 mm Hg at 25°C.

The principal use of 1,2-dichloroethylene (mixed isomers) is to produce vinyl chloride. It is used as a lead scavenger in gasoline, general solvent, and for synthesis of various other organic chemicals. When it is used as a solvent, 1,2-trans-DCE can enter wastewater streams.

Although 1,2-trans-DCE is thought to produce fatty degeneration of mammalian liver, there are insufficient data on which to base any ambient water criterion.

In the reported toxicity test of 1,2-trans-DCE on aquatic life, the compound appeared to be about half as toxic as the other dichloroethylene (1,1-DCE) on the toxic pollutants list.

The behavior of 1,2-trans-DCE in a POTW has not been studied. However, its high vapor pressure is expected to result in release of a significant percentage of this compound to the atmosphere in any treatment involving aeration. Degradation of the dichloroethylenes in air is reported to occur, with a half-life of eight weeks.

Biochemical oxidation of many of the toxic organic pollutants has been investigated in laboratory scale studies at concentrations higher than would normally be expected in municipal wastewaters. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by the study of the limited data is that biochemical oxidation produces little or no degradation of 1,2-trans-dichloroethylene. No evidence is available for drawing conclusions about the possible toxic or inhibitory effect of 1,2-trans-dichloroethylene on POTW operation. It is expected that its low molecular weight and degree of water solubility will result in 1,2-trans-DCE passing through a POTW to the effluent if it is not degraded or volatilized. Very little 1,2-trans-DCE is expected to be found in sludge from a POTW.

2,4-Dimethylphenol (34). 2,4-Dimethylphenol (2,4-DMP), also called 2,4-xylenol, is a colorless, crystalline solid at room temperature (25°C), but melts at 27°C to 28°C. 2,4-DMP is slightly soluble in water and, as a weak acid, is soluble in alkaline solutions. Its vapor pressure is less than 1 mm Hg at room temperature.

2,4-DMP is a natural product, occurring in coal and petroleum sources. It is used commercially as an intermediate for manufacture of pesticides, dye stuffs, plastics and resins, and surfactants. It is found in the water runoff from asphalt surfaces. It can find its way into the wastewater of a manufacturing plant from any of several adventitious sources.

Analytical procedures specific to this compound are used for its identification and quantification in wastewaters. This compound does not contribute to "Total Phenols" determined by the 4-aminoantipyrene method.

Three methylphenol isomers (cresols) and six dimethylphenol isomers (xylenols) generally occur together in natural products, industrial processes, commercial products, and phenolic wastes. Therefore, data are not available for human exposure to 2,4-DMP alone. In addition to this, most mammalian tests for toxicity of individual dimethylphenol isomers have been conducted with isomers other than 2,4-DMP.

In general, the mixtures of phenol, methylphenols, and dimethylphenols contain compounds which produced acute poisoning in laboratory animals. Symptoms were difficult breathing, rapid muscular spasms, disturbance of motor coordination, and asymmetrical body position. In a 1977 National Academy of Science publication the conclusion was reached that, "In view of the relative paucity of data on the mutagenicity, carcinogenicity, teratogenicity, and long term oral toxicity of 2,4-dimethylphenol, estimates of the effects of chronic oral exposure at low levels cannot be made with any confidence." No ambient water quality criterion can be set at this time. In order to protect public health, exposure to this compound should be minimized as soon as possible.

Toxicity data for fish and freshwater aquatic life are limited; however, in reported studies of 2,4-dimethylphenol at concentrations as high as 2 mg/l no adverse effects were observed.

The behavior of 2,4-DMP in a POTW has not been studied. As a weak acid, its behavior may be somewhat dependent on the pH of the influent to the POTW. However, over the normal limited range of POTW pH, little effect of pH would be expected.

Biological degradability of 2,4-DMP as determined in one study, showed 94.5 percent removal based on chemical oxygen demand (COD). Thus, substantial removal is expected for this compound. Another study determined that persistance of 2,4-DMP in the environment is low, and thus any of the compound which remained in the sludge or passed through the POTW into the effluent would be degraded within moderate length of time (estimated as two months in the report).

2,4-Dinitrotoluene (35). 2,4-Dinitrotoluene [$(NO_2)_2C_6H_4CH_3$], a yellow crystalline compound, is manufactured as a coproduct with the 2,6-isomer by nitration of nitrotoluene. It melts at 71°C. 2,4-Dinitrotoluene is insoluble in water (0.27 g/l at 22°C) and soluble in a number of organic solvents. Production data for the 2,4-isomer alone are not available. The 2,4-and 2,6-isomers are manufactured in an 80:20 or 65:35 ratio, depending on the process used. Annual U.S. commercial production is about 150 thousand tons of the two isomers. Unspecified amounts are produced by the U.S. government and further nitrated to trinitrotoluene (TNT) for military use. The major use of the dinitrotoluene mixture is for production of toluene diisocyanate used to make polyurethanes. Another use is in production of dyestuffs.

The toxic effect of 2,4-dinitrotoluene in humans is primarily methemoglobinemia (a blood condition hindering oxygen transport by the blood). Symptoms depend on severity of the disease, but include cyanosis, dizziness, pain in joints, headache, and loss of appetite in workers inhaling the compound. Laboratory animals fed oral doses of 2,4-dinitrotoluene exhibited many of the same symptoms. Aside from the effects in red blood cells, effects are observed in the nervous system and testes.

Chronic exposure to 2,4-dinitrotoluene may produce liver damage and reversible anemia. No data were found on teratogenicity of this compound. Mutagenic data are limited and are regarded as confusing. Data resulting from studies of carcinogenicity of 2,4-dinitrotoluene point to a need for further testing for this property.

For the maximum protection of human health from the potential carcinogenic effects of exposure to 2,4-dinitrotoluene through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of 2,4-dinitrotoluene estimated to result in additional lifetime cancer risk at risk levels of 10^{-7}, 10^{-6}, and 10^{5} are 7.4 ug/l, 74 ug/l, and 740 ug/l, respectively.

Data on the behavior of 2,4-dinitrotoluene in a POTW are not available. However, biochemical oxidation of 2,4-dinitrophenol was investigated on a laboratory scale. At 100 mg/l of 2,4-dinitrotoluene, a concentration considerably higher than that expected in municipal wastewaters, biochemical oxidation by an acclimated, phenol-adapted seed culture produced 52 percent degradation in three hours. Based on this limited information and general observations relating molecular structure to ease of degradation for all the toxic organic pollutants, it was concluded that biological treatment in a POTW removes 2,4-dinitrotoluene to a high degree or completely. No information is available regarding possible interference by 2,4-dinitrotoluene in POTW treatment processes, or on the possible detrimental effect on sludge used to ammend soils in which food crops are grown.

Ethylbenzene (38). Ethylbenzene is a colorless, flammable liquid manufactured commercially from benzene and ethylene. Approximately half of the benzene used in the U.S. goes into the manufacture of more than three million tons of ethylbenzene annually. Ethylbenzene boils at 136°C and has a vapor pressure of 7 mm Hg at 20°C. It is slightly soluble in water (0.14 g/l at 15°C) and is very soluble in organic solvents.

About 98 percent of the ethylbenzene produced in the U.S. goes into the production of styrene, much of which is used in the plastics and synthetic rubber industries. Ethylbenzene is a constituent of xylene mixtures used as diluents in the paint industry, agricultural insecticide sprays, and gasoline blends.

Although humans are exposed to ethylbenzene from a variety of sources in the environment, little information on effects of ethylbenzene in man or animals is available. Inhalation can irritate eyes, affect the respiratory tract, or cause vertigo. In laboratory animals ethylbenzene exhibited low toxicity. There are no data available on teratogenicity, mutagenicity, or carcinogenicity of ethylbenzene.

Criteria are based on data derived from inhalation exposure limits. For the protection of human health from the toxic properties of ethylbenzene ingested through water and contaminated aquatic organisms, the ambient water quality criterion is 1.1 mg/l.

The behavior of ethylbenzene in a POTW has not been studied in detail. Laboratory scale studies of the biochemical oxidation of ethylbenzene at concentrations greater than would normally be found in municipal wastewaters have demonstrated varying degrees of degradation. In one study with phenol-acclimated seed cultures, 27 percent degradation was observed in a half day at 250 mg/l ethylbenzene. Another study at unspecified conditions showed 32, 38, and 45 percent degradation after 5, 10, and 20 days, respectively. Based on these results and general observations relating molecular structure of degradation, the conclusion is reached that biological treatment produces only moderate removal of ethylbenzene in a POTW by degradation.

Other studies suggest that most of the ethybenzene entering a POTW is removed from the aqueous stream to the sludge. The ethylbenzene contained in the sludge removed from the POTW may volatilize.

Fluoranthene (39). Fluoranthene (1,2-benzacenaphthene) is one of the compounds called polynuclear aromatic hydrocarbons (PAH). A pale yellow solid at room temperature, it melts at 111°C and has a negligible vapor pressure at 25°C. Water solubility is low (0.2 mg/l). Its molecular formula is $C_{16}H_{10}$.

Fluoranthene, along with many other PAH's, is found throughout the environment. It is produced by pyrolytic processing of organic raw materials, such as coal and petroleum, at high temperature (coking processes). It occurs naturally as a product of plant biosyntheses. Cigarette smoke contains fluoranthene. Although it is not used as the pure compound in industry, it has been found at relatively higher concentrations (0.002 mg/l) than most other PAH's in at least one industrial effluent. Furthermore, in a 1977 EPA survey to determine levels of PAH in U.S. drinking water supplies, none of the 110 samples analyzed showed any PAH other than fluoranthene.

Experiments with laboratory animals indicate that fluoranthene presents a relatively low degree of toxic potential from acute exposure, including oral administration. Where death occurred, no information was reported concerning target organs or specific cause of death.

There is no epidemiological evidence to prove that PAH in general, and fluoranthene, in particular, present in drinking water are related to the development of cancer. The only studies directed toward determining carcinogenicity of fluoranthene have been skin tests on laboratory animals. Results of these tests show that fluoranthene has no activity as a complete carcinogen (i.e., an agent which produces cancer when applied by itself), but exhibits significant cocarcinogenicity (i.e., in combination with a carcinogen, it increases the carcinogenic activity).

Based on the limited animal study data, and following an established procedure, the ambient water quality criterion for fluoranthene alone (not in combination with other PAH) is determined to be 200 mg/l for the protection of human health from its toxic properties.

There are no data on the chronic effects of fluoranthene on freshwater organisms. One saltwater invertebrate shows chronic toxicity at concentrations below 0.016 mg/l. For some freshwater fish species the concentrations producing acute toxicity are substantially higher, but data are very limited.

Results of studies of the behavior of fluoranthene in conventional sewage treatment processes found in a POTW have been published. Removal of fluoranthene during primary sedimentation was found to be 62 to 66 percent (from an initial value of 0.00323 to 0.04435 mg/l to a final value of 0.00122 to 0.0146 mg/l), and the removal was 91 to 99 percent (final values of 0.00028 to 0.00026 mg/l) after biological purification with activated sludge processes.

A review was made of data on biochemical oxidation of many of the toxic organic pollutants investigated in laboratory scale studies at concentrations higher than would normally be expected in municipal wastewaters. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by study of the limited data is that biological treatment produces little or no degradation of fluoranthene. The same study, however, concludes that fluoranthene would be readily removed by filtration and oil-water separation and other methods which rely on water insolubility, or adsorption on other particulate surfaces. This latter conclusion is supported by the previously cited study showing significant removal by primary sedimentation.

No studies were found to give data on either the possible interference of fluoranthene with POTW operation, or the persistance of fluoranthene in sludges or POTW effluent waters. Several studies have documented the ubiquity of fluoranthene in the environment and it cannot be readily determined if this results from persistence of anthropogenic fluoranthene or the replacement of degraded fluoranthene by natural processes such as biosynthesis in plants.

Methylene Chloride (44). Methylene chloride, also called dichloromethane (CH_2Cl_2), is a colorless liquid manufactured by chlorination of methane or methyl chloride followed by separation from the higher chlorinated methanes formed as coproducts. Methylene chloride boils at 40°C, and has a vapor pressure of 362 mm Hg at 20°C. It is slightly soluble in water (20 g/l at 20°C), and very soluble in organic solvents. U.S. annual production is about 250,000 tons.

Methylene chloride is a common industrial solvent found in insecticides, metal cleaners, paint, and paint and varnish removers.

Methylene chloride is not generally regarded as highly toxic to humans. Most human toxicity data are for exposure by inhalation. Inhaled methylene chloride acts as a central nervous system depressant. There is also evidence that the compound causes heart failure when large amounts are inhaled.

Methylene chloride does produce mutation in tests for this effect. In addition, a bioassay recognized for its extremely high sensitivity to strong and weak carcinogens produced results which were marginally significant. Thus potential carcinogenic effects of methylene chloride are not confirmed or denied, but are under continuous study. Difficulty in conducting and interpreting the test results from the low boiling point (40°C) of methylene chloride which increases the difficulty of maintaining the compound in growth media during incubation at 37°C; and from the difficulty of removing all impurities, some of which might themselves be carcinogenic.

For the protection of human health from the toxic properties of methylene chloride ingested through water and contaminated aquatic organisms, the ambient water criterion is 0.002 mg/l. The behavior of methylene chloride in a POTW has not been studied in any detail. However, the biochemical oxidation of this compound was studied in one laboratory scale study at concentrations higher than those expected to be contained by most municipal wastewaters. After five days no degradation of methylene chloride was observed. The conclusion reached is that biological treatment produces little or no removal by degradation of methylene chloride in a POTW.

The high vapor pressure of methylene chloride is expected to result in volatilization of the compound from aerobic treatment steps in a POTW. It has been reported that methylene chloride inhibits anerobic processes in a POTW. Methylene chloride that is not volatilized in the POTW is expected to pass through into the effluent.

Dichlorobromomethane (48). This compound is a halogenated aliphatic. Research has been shown that halomethanes have carcinogenic properties, and exposure to this compound may have adverse effects on human health.

Isophorone (54). Isophorone is an industrial chemical produced at a level of tens of millions of pounds annually in the U.S. The chemical name for isophorone is 3,5,5-trimethyl-2-cyclohexen-1-one and it is also known as trimethyl cyclohexanone and isoacetophorone. The formula is $C_6H_5(CH_3)_3O$. Normally, it is produced as the gamma isomer; technical grades contain about 3 percent of the beta isomer (3,5,5-trimethyl-3-cyclohexen-1-one). The pure gamma isomer is a water-white liquid, with vapor pressure less than 1 mm Hg at room temperature, and a boiling point of 215.2°C. It has a camphor- or peppermint-like odor and yellows upon standing. It is slightly soluble (12 mg/l) in water and dissolves in fats and oils.

Isophorone is synthesized from acetone and is used commercially as a solvent or cosolvent for finishes, lacquers, polyvinyl and nitrocellulose resins, pesticides, herbicides, fats, oils, and gums. It is also used as a chemical feedstock.

Because isophorone is an industrially used solvent, most toxicity data are for inhalation exposure. Oral administration to laboratory animals in two different studies revealed no acute or chronic effects during 90 days, and no hematological or pathological abnormalities were reported. Apparently, no studies have been completed on the carcinogenicity of isophorone.

Isophorone does undergo bioconcentration in the lipids of aquatic organisms and fish.

Based on subacute data, the ambient water quality criterion for isophorone ingested through consumption of water and fish is set at 460 mg/l for the protection of human health from its toxic properties.

Studies of the effects of isophorone on fish and aquatic organisms reveal relatively low toxicity, compared to some other toxic pollutants.

The behavior of isophorone in a POTW has not been studied. However, the biochemical oxidation of many of the toxic organic pollutants has been investigated in laboratory scale studies at concentrations higher than would normally be expected in municipal wastewaters. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by the study of the limited data is that biochemical treatment in a POTW produces moderate removal of isophorone. This conclusion is consistent with the findings of an experimental study of microbiological degradation of isophorone which showed about 45 percent oxidation in 15 to 20 days in domestic wastewater, but only 9 percent in salt water. No data were found on the persistence of isophorone in sewage sludge.

Naphthalene (55). Naphthalene is an aromatic hydrocarbon with two orthocondensed benzene rings and a molecular formula of $C_{10}H_8$. As such it is properly classed as a polynuclear aromatic hydrocarbon (PAH). Pure naphthalene is a white crystalline solid melting at 80°C. For a solid, it has a relatively high vapor pressure (0.05 mm Hg at 20°C), and moderate water solubility (19 mg/l at 20°C). Napthalene is the most abundant single component of coal tar. Production is more than a third of a million tons annually in the U.S. About three fourths of the production is used as feedstock for phthalic anhydride manufacture. Most of the remaining production goes into manufacture of insecticide, dyestuffs, pigments, and pharmaceuticals. Chlorinated and partially hydrogenated naphthalenes are used in some solvent mixtures. Naphthalene is also used as a moth repellent.

Naphthalene, ingested by humans, has reportedly caused vision loss (cataracts), hemolytic anemia, and occasionally, renal disease. These effects of naphthalene ingestion are confirmed by studies on laboratory animals. No carcinogenicity studies are available which can be used to demonstrate carcinogenic activity for naphthalene. Naphthalene does bioconcentrate in aquatic organisms.

For the protection of human health from the toxic properties of naphthalene ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 143 mg/l.

Only a limited number of studies have been conducted to determine the effects of naphthalene on aquatic organisms. The data from those studies show only moderate toxicity.

Naphthalene has been detected in sewage plant effluents at concentrations up to 0.022 mg/l in studies carried out by the U.S. EPA. Influent levels were not reported. The behavior of naphthalene in a POTW has not been studied. However, recent studies have determined that naphthalene will accumulate in sediments at 100 times the concentration in overlying water. These results suggest that naphthalene will be readily removed by primary and secondary settling in a POTW, if it is not biologically degraded.

Biochemical oxidation of many of the toxic organic pollutants has been investigated in laboratory scale studies at concentrations higher than would normally be expected in municipal wastewaters. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by study of the limited data is that biological treatment produces a high removal by degradation of naphthalene. One recent study has shown that microorganisms can degrade naphthalene, first to a dihydro compound, and ultimately to carbon dioxide and water.

Nitrobenzene (56). Nitrobenzene ($C_6H_5NO_2$), also called nitrobenzol and oil of mirbane, is a pale yellow, oily liquid, manufactured by reacting benzene with nitric acid and sulfuric acid. Nitrobenzene boils at 210°C and has a vapor pressure of 0.34 mm Hg at 25°C. It is slightly soluble in water (1.9 g/l at 20°C), and is miscible with most organic solvents. Estimates of annual U.S production vary widely, ranging from 100 to 350 thousand tons.

Almost the entire volume of nitrobenzene produced (97 percent) is converted to aniline, which is used in dyes, rubber, and medicinals. Other uses for nitrobenzene include: solvent for organic synthesis, metal polishes, shoe polish, and perfume.

The toxic effects of ingested or inhaled nitrobenzene in humans are related to its action in blood: methemoglobinemia and cyanosis. Nitrobenzene administered orally to laboratory animals caused degeneration of heart, kidney, and liver tissue; paralysis; and death. Nitrobenzene has also exhibited teratogenicity in laboratory animals, but studies conducted to determine mutagenicity or carcinogenicity did not reveal either of these properties.

For the prevention of adverse effets due to the organoleptic properties of nitrobenzene in water, the criterion is 0.030 mg/l.

Data on the behavior of nitrobenzene in POTW are not available. However, laboratory scale studies have been conducted at concentrations higher than those expected to be found in municipal wastewaters. Biochemical oxidation produced no degradation after 5, 10, and 20 days. A second study also reported no degradation after 28 hours, using an acclimated, phenol-adapted seed culture with nitrobenzene at 100 mg/l. Based on these limited data, and on general observations relating molecular structure to ease of biological oxidation, it is concluded that little or no removal of nitrobenzene occurs during biological treatment in POTW. The low water solubility and low vapor pressure of nitrobenzene lead to the expectation that nitrobenzene will be removed from POTW in the effluent and by volatilization during aerobic treatment.

4-Nitrophenol (58). 4-Nitrophenol ($NO_2C_6H_4OH$), also called paranitrophenol, is a colorless to yellowish crystalline solid manufactured commercially by hydrolysis of 4-chloro-nitrobenzene with aqueous sodium hydroxide. 4-Nitrophenol melts at 114°C. Vapor pressure is not cited in the usual sources. 4-Nitrophenol is slightly soluble in water (15 g/l at 25°C) and soluble in organic solvents. This phenol does not react to give a color with 4-aminoantipyrene, and therefore does not contribute to the nonconventional pollutant parameter "Total Phenols." U.S. annual production is about 20,000 tons.

Paranitrophenol is used to prepare phenetidine, acetaphenetidine, azo and sulfur dyes, photochemicals, and pesticides.

The toxic effects of 4-nitrophenol on humans have not been extensively studied. Data from experiments with laboratory animals indicate that exposure to this compound results in methmoglobinemia (a metabolic disorder of blood), shortness of breath, and stimulation followed by depression. Other studies indicate that the compound acts directly on cell membranes, and inhibits certain enzyme systems in vitro. No information regarding potential teratogenicity was found. Available data indicate that this compound does not pose a mutagenic hazard to humans. Very limited data for 4-nitrophenol do not reveal potential carcinogenic effects, although the compound has been selected by the national cancer institute for testing under the Carcinogenic Bioassay Program.

No U.S. standards for exposure to 4-nitrophenol in ambient water have been established.

Data on the behavior of 4-nitrophenol in a POTW are not available. However, laboratory scale studies have been conducted at concentrations higher than those expected to be found in municipal wastewaters. Biochemical oxidation using adapted cultures from various sources produced 95 percent degradation in three to six days in one study. Similar results were reported for other studies. Based on these data, and on general observations relating molecular structure to ease of biological oxidation, it is concluded that complete or nearly complete removal of 4-nitrophenol occurs during biological treatment in a POTW.

2,4,-Dinitrophenol (59). 2,4-Dinitrophenol [$(NO_2)_2C_6H_3OH$], a yellow crystalline solid, is manufactured commercially by hydrolysis of 2,4-dinitro-1-chlorobenzene with sodium hydroxide. 2,4-Dinitrophenol sublimes at 114°C. Vapor pressure is not cited in usual sources. It is slightly soluble in water (7.0 g/l at 25°C) and soluble in organic solvents. This phenol does not react with 4-aminoantipyrene and therefore does not contribute to the nonconventional pollutant parameter "Total Phenols." U.S. annual production is about 500 tons.

2,4-Dinitrophenol is used to manufacture sulfur and azo dyes, photochemicals, explosives, and pesticides.

The toxic effects of 2,4-dinitrophenol in humans is generally attributed to their ability to uncouple oxidative phosphorylation. In brief, this means that sufficient 2,4-dinitrophenol short-circuits cell metabolism by preventing utilization of energy provided by respiration and glycolysis. Specific symptoms are gastrointestinal disturbances, weakness, dizziness, headache, and loss of weight. More acute poisoning includes symptoms such as: burning thirst, agitation, irregular breathing, and abnormally high fever. This compound also inhibits other enzyme systems; and acts directly on the cell membrane, inhibiting chloride permeability. Ingestion of 2,4-dinitrophenol also causes cataracts in humans.

Based on available data it appears unlikely that 2,4-dinitrophenol poses a teratogenic hazard to humans. Results of studies of mutagenic activity of this compound are inconclusive as far as humans are concerned. Available data suggest that 2,4-dinitrophenol does not possess carcinogenic properties.

To protect human health from the adverse effects of 2,4-dinitrophenol ingested in contaminated water and fish, the suggested water quality criterion is 0.0686 mg/l .

Data on the behavior of 2,4-dinitrophenol in a POTW are not available. However, laboratory scale studies have been conducted at concentrations higher than those expected to be found in municipal wastewaters. Biochemical oxidation using a phenol-adapted seed culture produced 92 percent degradation in 3.5 hours. Similar results were reported for other studies. Based on these data, and on general observations relating molecular structure to ease of biological oxidation, it is concluded that complete or nearly complete removal of 2,4-dinitrophenol occurs during biological treatment in a POTW.

N-nitrosodiphenylamine (62). N-nitrosodiphenylamine [$(C_6H_5)_2NNO$], also called nitrous diphenylamide, is a yellow crystalline solid manufactured by nitrosation of diphenylamine. It melts at 66°C and is insoluble in water, but soluble in several organic solvents other than hydrocarbons. Production in the U.S. has approached 1,500 tons per year. The compound is used as a retarder for rubber vulcanization and as a pesticide for control of scorch (a fungus disease of plants).

N-nitroso compounds are acutely toxic to every animal species tested and are also poisonous to humans. N-nitrosodiphenylamine toxicity in adult rats lies in the mid range of the values for 60 N-nitroso compounds tested. Liver damage is the principal toxic effect. N-nitrosodiphenylamine, unlike many other N-nitrosoamines, does not show mutagenic activity. N-nitrosodiphenylamine has been reported by several investigations to be non-carcinogenic. However, the compound is capable of trans-nitrosation and could thereby convert other amines to carcinogenic N-nitrosoamines. Sixty-seven of 87 N-nitrosoamines studied were reported to have carcinogenic activity. No water quality criterion have been proposed for N-nitrosodiphenylamine.

No data are available on the behavior of N-nitrosodiphenylamine in a POTW. Biochemical oxidation of many of the toxic organic pollutants have been investigated, at least in laboratory scale studies, at concentrations higher than those expected to be contained in most municipal wastewaters. General observations have been developed relating molecular structure to ease of degradation for all the toxic organic pollutants. The conclusion reached by study of the limited data is that biological treatment produces little or no removal of N-nitrosodiphenylamine in a POTW. No information is available regarding possible interference by N-nitrosodiphenylamine in POTW processes, or on the possible detrimental effect on sludge used to amend soils in which crops are grown. However, no interference or detrimental effects are expected because N-nitroso compounds are widely distributed in the soil and water environment, at low concentrations, as a result of microbial action on nitrates and nitrosatable compounds.

Pentachlorophenol (64). Pentachlorophenol (C_6Cl_5OH) is a white crystalline solid produced commercially by chlorination of phenol or polychlorophenols. U.S. annual production is in excess of 20,000 tons. Pentachlorophenol melts at 190°C and is slightly soluble in water (14 mg/l). Pentachlorophenol is not detected by the 4-amino antipyrene method.

Pentachlorophenol is a bactericide and fungicide and is used for preservation of wood and wood products. It is competitive with creosote in that application. It is also used as a preservative in glues, starches, and photographic papers. It is an effective algicide and herbicide.

Although data are available on the human toxicity effects of pentachlorophenol, interpretation of data is frequently uncertain. Occupational exposure observations must be examined carefully because exposure to pentachlorophenol is frequently accompanied by exposure to other wood preservatives. Additionally, experimental results and occupational exposure observations must be examined carefully to make sure that observed effects are produced by the pentachlorophenol itself and not by the by-products which usually contaminate pentachlorophenol.

Acute and chronic toxic effects of pentachlorophenol in humans are similar; muscle weakness, headache, loss of appetite, abdominal pain, weight loss, and irritation of skin, eyes, and respiratory tract. Available literature indicates that pentachlorophenol does not accumulate in body tissues to any significant extent. Studies on laboratory animals of distribution of the compound in body tissues showed the highest levels of pentachlorophenol in liver, kidney, and intestine, while the lowest levels were in brain, fat, muscle, and bone.

Toxic effects of pentachlorophenol in aquatic organisms are much greater at pH 6 where this weak acid is predominantly in the undissociated form than at pH 9 where the ionic form predominates. Similar results were observed in mammals where oral lethal doses of pentachlorophenol were lower when the compound was administered in hydrocarbon solvents (un-ionized form) than when it was administered as the sodium salt (ionized form) in water.

There appear to be no significant teratogenic, mutagenic, or carcinogenic effects of pentachlorophenol.

For the protection of human health from the toxic properties of pentachlorophenol ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 0.140 mg/l.

Only limited data are available for reaching conclusions about the behavior of pentachlorophenol in a POTW. Pentachlorophenol has been found in the influent to a POTW. In a study of one POTW the mean removal was 59 percent over a seven day period. Trickling filters removed 44 percent at the influent pentachlorophenol, suggesting that biological degradation occurs. The same report compared removal of pentachlorophenol at the same plant and two additional POTW facilities on a later date and obtained values of

4.4, 19.5 and 28.6 percent removal, the last value being for the plant which was 59 percent removal in the original study. Influent concentrations of pentachlorophenol ranged from 0.0014 to 0.0046 mg/l. Other studies, including the general review of data relating molecular structure to biological oxidation, indicate that pentachlorophenol is not removed by biological treatment processes in a POTW. Anaerobic digestion processes are inhibited by 0.4 mg/l pentachlorophenol.

The low water solubility and low volatility of pentachlorophenol lead to the expectation that most of the compound will remain in the sludge in a POTW. The effect on plants grown on land treated with pentachlorophenol-containing sludge is unpredictable. Laboratory studies show that this compound affects crop germination at 5.4 mg/l. However, photodecomposition of pentachlorophenol occurs in sunlight. The effects of the various breakdown products which may remain in the soil was not found in the literture.

Phenol (65). Phenol, also called hydroxybenzene and carbolic acid, is a clear, colorless, hygroscopic, deliquescent, crystalline solid at room temperature. Its melting point is 43°C and its vapor pressure at room temperature is 0.35 mm Hg. It is very soluble in water (67 gm/l at 16°C) and can be dissolved in benzene, oils, and petroleum solids. Its formula is C_6H_5OH.

Although a small percent of the annual production of phenol is derived from coal tar as a naturally occuring product, most of the phenol is synthesized. Two of the methods are fusion of benzene sulfonate with sodium hydroxide, and oxidation of cumene followed by cleavage with a catalyst. Annual production in the U.S. is in excess of one million tons. Phenol is generated during distillation of wood and the microbiological decomposition of organic matter in the mammalian intestinal tract.

Phenol is used as a disinfectant, in the manufacture of resins, dyestuffs, and in pharmaceuticals, and in the photo processing industry. In this discussion, phenol is the specific compound which is separated by methylene chloride extraction of an acidified sample and identified and quantified by GC/MS. Phenol also contributes to the "Total Phenols," discussed elsewhere which are determined by the 4-AAP colorimetric method.

Phenol exhibits acute and sub-acute toxicity in humans and laboratory animals. Acute oral doses of phenol in humans cause sudden collapse and unconsciousness by its action on the central nervous system. Death occurs by respiratory arrest. Sub-acute oral doses in mammals are rapidly absorbed and quickly distributed to various organs, then cleared from the body by urinary excretion and metabolism. Long term exposure by drinking phenol contaminated water has resulted in statistically significant increase in reported cases of diarrhea, mouth sores, and burning of the mouth. In laboratory animals, long term oral administration at low levels produced slight liver and kidney damage. No reports were found regarding carcinogenicity of phenol administered orally - all carcinogenicity studies were skin test.

For the protection of human health from phenol ingested through water and through contaminated aquatic organisms, the concentration in water should not exceed 3.4 mg/l.

Fish and other aquatic organisms demonstrated a wide range of sensitivities to phenol concentration. However, acute toxicity values were at moderate levels when compared to other toxic organic pollutants.

Data have been developed on the behavior of phenol in a POTW. Phenol is biodegradable by biota present in a POTW. The ability of a POTW to treat phenol-bearing influents depends upon acclimation of the biota and the constancy of the phenol concentration. It appears that an induction period is required to build up the population of organisms which can degrade phenol. Too large a concentration will result in upset or pass though in the POTW, but the specific level causing upset depends on the immediate past history of phenol concentrations in the influent. Phenol levels as high as 200 mg/l have been treated with 95 percent removal in a POTW, but more or less continuous presence of phenol is necessary to maintain the population of microorganisms that degrade phenol.

Phenol which is not degraded is expected to pass through the POTW because of its very high water solubility. However, in a POTW where chlorination is practiced for disinfection of the POTW effluent, chlorination of phenol may occur. The products of that reaction may be toxic pollutants.

The EPA has developed data on influent and effluent concentrations of total phenols in a study of 103 POTW facilities. However, the analytical procedure was the 4-AAP method mentioned earlier and not the GC/MS method specifically for phenol. Discussion of the study, which of course includes phenol, is presented under the pollutant heading "Total Phenols."

Phthalate Esters (66-71). Phthalic acid, or 1,2-benzenedicarboxylic acid, is one of three isomeric benzenedicarboxylic acids produced by the chemical industry. The other two isomeric forms are called isophthalic and terephthalic acids. The formula for all three acids is $C_6H_4(COOH)_2$. Some esters of phthalic acid are designated as toxic pollutants. They will be discussed as a group here, and specific properties of individual phthalate esters will be discussed afterwards.

Phthalic acid esters are manufactured in the U.S. at an annual rate in excess of one billion pounds. They are used as plasticizers - primarily in the production of polyvinyl chloride (PVC) resins. The most widely used phthalate plasticizer is bis (2-ethylhexyl) phthalate (66) which accounts for nearly one-third of the phthalate esters produced. This particular ester is commonly referred to as dioctyl phthalate (DOP) and should not be confused with one of the less used esters, di-n-octyl phthalate (69), which is also used as a plasticizer. In addition to these two isomeric dioctyl phthalates, four other esters, also used primarily as plasticizers, are designated as toxic pollutants. They are: butyl benzyl phthalate (67), di-n-butyl phthalate (68), diethyl phthalate (70), and dimethyl phthalate (71).

Industrially, phthalate esters are prepared from phthalic anhydride and the specific alcohol to form the ester. Some evidence is available suggesting that phthalic acid esters also may be synthesized by certain plant and animal tissues. The extent to which this occurs in nature is not known.

Phthalate esters used as plasticizers can be present in concentrations up to 60 percent of the total weight of the PVC plastic. The plasticizer is not linked by primary chemical bonds to the PVC resin. Rather, it is locked into the structure of intermeshing polymer molecules and held by van der Waals forces. The result is that the plasticizer is easily extracted. Plasticizers are responsible for the odor associated with new plastic toys or flexible sheet that has been contained in a sealed package.

Although the phthalate esters are not soluble or are only very slightly soluble in water, they do migrate into aqueous solutions placed in contact with the plastic. Thus, industrial facilities with tank linings, wire and cable coverings, tubing, and sheet flooring of PVC are expected to discharge some phthalate esters in their raw waste. In addition to their use as plasticizers, phthalate esters are used in lubricating oils and pesticide carriers. These also can contribute to industrial discharge of phthalate esters.

From the accumulated data on acute toxicity in animals, phthalate esters may be considered as having a rather low order of toxicity. Human toxicity data are limited. It is thought that the toxic effects of the esters is most likely due to one of the metabolic products, in particular the monoester. Oral acute toxicity in animals is greater for the lower molecular weight esters than for the higher molecular weight esters.

Orally administered phthalate esters generally produced enlarging of liver and kidney, and atrophy of testes in laboratory animals. Specific esters produced enlargement of heart and brain, spleenitis, and degeneration of central nervous system tissue.

Subacute doses administered orally to laboratory animals produced some decrease in growth and degeneration of the testes. Chronic studies in animals showed similar effects to those found in acute and subacute studies, but to a much lower degree. The same organs were enlarged, but pathological changes were not usually detected.

A recent study of several phthalic esters produced suggestive but not conclusive evidence that dimethyl and diethyl phthalates have a cancer liability. Only four of the six toxic pollutant esters were included in the study. Phthalate esters do bioconcentrate in fish. The factors, weighted for relative consumption of various aquatic and marine food groups, are used to calculate ambient water quality criteria for four phthalate esters. The values are included in the discussion of the specific esters.

Studies of toxicity of phthalate esters in freshwater and salt water organisms are scarce. A chronic toxicity test with bis(2-ethylhexyl) phthalate showed that significant reproductive impairment occurred at 0.003 mg/l in the freshwater crustacean, Daphnia magna. In acute toxicity studies, saltwater fish and organisms showed sensitivity differences of up to eight-fold to butyl benzyl, diethyl, and dimethyl phthalates. This suggests that each ester must be evaluated individually for toxic effects.

The behavior of phthalate esters in a POTW has not been studied. However, the biochemical oxidation of many of the toxic organic pollutants has been investigated in laboratory scale studies at concentrations higher than would normally be expected in municipal wastewaters. Three of the phthalate esters were studed. Bis(2-ethylhexyl) phthalate was found to be degraded slightly or not at all and its removal by biological treatment in a POTW is expected to be slight or zero. Di-n-butyl phthalate and diethyl phthalate were degraded to a moderate degree and their removal by biological treatment in a POTW is expected to occur to a moderate degree. Using these data and other observations relating molecular structure to ease of biochemical degradation of other toxic organic pollutants, the conclusion was reached that butyl benzyl phthalate and dimethyl phthalate would be removed in a POTW to a moderate degree by biological treatment. On the same basis, it was concluded that di-n-octyl phthalate would be removed to a slight degree or not at all. An EPA study of seven POTW facilities revealed that for all but di-n-octyl phthalate, which was not studied, removals ranged from 62 to 87 percent.

No information was found on possible interference with POTW operation or the possible effects on sludge by the phthalate esters. The water insoluble phthalate esters - butyl benzyl and di-n-octyl phthalate - would tend to remain in sludge, whereas the other four toxic pollutant phthalate esters with water solubilities ranging from 50 mg/l to 4.5 mg/l would probably pass through into the POTW effluent.

Bis(2-ethylhexyl) phthalate (66). In addition to the general remarks and discussion on phthalate esters, specific information on bis(2-ethylhexyl) phthalate is provided. Little information is available about the physical properties of bis(2-ethylhexyl) phthalate. It is a liquid boiling at 387°C at 5mm Hg and is insoluble in water. Its formula is $C_6H_4(COOC_8H_{17})_2$. This toxic pollutant constitutes about one-third of the phthalate ester production in the U.S. It is commonly referred to as dioctyl phthalate, or DOP, in the plastics industry where it is the most extensively used compound for the plasticization of polyvinyl chloride (PVC). Bis(2-ethylhexyl) phthalate has been approved by the FDA for use in plastics in contact with food. Therefore, it may be found in wastewaters coming in contact with discarded plastic food wrappers as well as the PVC films and shapes normally found in industrial plants. This toxic pollutant is also a commonly used organic diffusion pump oil, where its low vapor pressure is an advantage.

For the protection of human health from the toxic properties of bis(2-ethylhexyl) phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 15 mg/l. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the ambient water criteria is determined to be 50 mg/l.

Although the behavior of bis(2-ethylhexyl) phthalate in a POTW has not been studied, biochemical oxidation of this toxic pollutant has been studied on a laboratory scale at concentrations higher than would normally be expected in municipal wastewater. In fresh water with a non-acclimated seed culture no biochemical oxidation was observed after 5, 10, and 20 days. However, with an acclimated seed culture, biological oxidation occured to the extents of 13, 0, 6, and 23 percent of theoretical after 5, 10, 15 and 20 days, respectively. Bis(2-ethylhexyl) phthalate concentrations were 3 to 10 mg/l. Little or no removal of bis(2-ethylhexyl) phthalate by biological treatment in a POTW is expected.

Butyl Benzyl Phthalate (67). In addition to the general remarks and discussion on phthalate esters, specific information on butyl benzyl phthalate is provided. No information was found on the physical properties of this compound.

Butyl benzyl phthalate is used as a plasticizer for PVC. Two special applications differentiate it from other phthalate esters. It is approved by the U.S. FDA for food contact in wrappers and containers; and it is the industry standard for plasticization of vinyl flooring because it provides stain resistance.

No ambient water quality criterion is proposed for butyl benzyl phthalate.

Butyl benzyl phthalate removal in a POTW by biological treatment is expected to occur to a moderate degree.

Di-n-butyl Phthalate (68). In addition to the general remarks and discussion on phthalate esters, specific information on di-n-butyl phthalate (DBP) is provided. DBP is a colorless, oil liquid, boiling at 340°C. Its water solubility at room temperature is reported to be 0.4 g/l and 4.5 g/l in two different chemistry handbooks. The formula for DBP, $C_6H_4(COOC_4H_9)_2$ is the same as for its isomer, di-isobutyl phthalate. DBP production is 1 to 2 percent of total U.S. phthalate ester production.

Dibutyl phthalate is used to a limited extent as a plasticizer for polyvinyl chloride (PVC). It is not approved for contact with food. It is used in liquid lipsticks and as a diluent for polysulfide dental impression materials. DBP is used as a plasticizer for nitrocellulose in making gun powder, and as a fuel in solid propellants for rockets. Further uses are insecticides, safety glass manufacture, textile lubricating agents, printing inks, adhesives, paper coatings, and resin solvents.

For protection of human health from the toxic properties of dibutyl phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 34 mg/l. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the ambient water criterion is 154 mg/l.

Although the behavior of di-n-butyl phthalate in a POTW has not been studied, biochemical oxidation of this toxic pollutant has been studied on a laboratory scale at concentrations higher than would normally be expected in municipal wastewaters. Biochemical oxidation of 35, 43, and 45 percent of theoretical oxidation were obtained after 5, 10, and 20 days, respectively, using sewage microorganisms as an unacclimated seed culture.

Biological treatment in a POTW is expected to remove di-n-butyl phthalate to a moderate degree.

Di-n-octyl Phthalate (69). In addition to the general remarks and discussion on phthalate esters, specific information on di-n-octyl phthalate is provided. Di-n-octyl phthalate is not to be confused with the isomeric bis(2-ethylhexyl) phthalate which is commonly referred to in the plastics industry as DOP. Di-n-octyl phthalate is a liquid which boils at 220°C at 5 mm Hg. It is insoluble in water. Its molecular formula is C_6H_4-$(COOC_8H_{17})_2$. Its production constitutes about 1 percent of all phthalate ester production in the U.S.

Industrially, di-n-octyl phthalate is used to plasticize polyvinyl chloride (PVC) resins.

No ambient water quality criterion is proposed for di-n-octyl phthalate.

Biological treatment in a POTW is expected to lead to little or no removal of di-n-octyl phthalate.

Diethyl Phthalate (70). In addition to the general remarks and discussion on phthalate esters, specific information on diethyl phthalate is provided. Diethyl phthalate, or DEP, is a colorless liquid boiling at 296°C, and is insoluble in water. Its molecular formula is $C_6H_4(COOC_2H_5)_2$. Production of diethyl phthalate constitutes about 1.5 percent of phthalate ester production in the U.S.

Diethyl phthalate is approved for use in plastic food containers by the U.S. FDA. In addition to its use as a polyvinyl chloride (PVC) plasticizer, DEP is used to plasticize cellulose nitrate for gun powder, to dilute polysulfide dental impression materials, and as an accelerator for dyeing triacetate fibers. An additional use which would contribute to its wide distribution in the environment is as an approved special denaturant for ethyl alcohol. The alcohol-containing products for which DEP is an approved denaturant include a wide range of personal care items such as bath preparations, bay rum, colognes, hair preparations, face and hand creams, perfumes and toilet soaps. Additionally, this denaturant is approved for use in biocides, cleaning solutions, disinfectants, insecticides, fungicides, and room deoderants which have ethyl alcohol as part of the formulation. It is expected, therefore, that people and buildings would have some surface loading of this toxic pollutant which would find its way into raw wastewaters.

For the protection of human health from the toxic properties of diethyl phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 350 mg/l. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the ambient water criterion is 1,800 mg/l.

Although the behavior of diethyl phthalate in a POTW has not been studied, biochemical oxidation of this toxic pollutant has been studied on a laboratory scale at concentrations higher than would normally be expected in municipal wastewaters. Biochemical oxidation of 79, 84, and 89 percent of theoretical was observed after 5, 15, and 20 days respectively. Biological treatment in a POTW is expected to lead to a moderate degree of removal of diethyl phthalate.

Dimethyl Phthalate (71). In addition to the general remarks and discussion on phthalate esters, specific information on dimethyl phthalate (DMP) is provided. DMP has the lowest molecular weight of the phthalate esters - M.W. = 194 compared to M.W. of 391 for bis(2-ethylhexyl) phthalate. DMP has a boiling point of 282°C. It is a colorless liquid, soluble in water to the extent of 5 mg/l. Its molecular formula is $C_6H_4(COOCH_3)_2$.

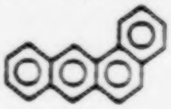
Dimethyl phthalate production in the U.S. is just under one percent of total phthalate ester production. DMP is used to some extent as a plasticizer in cellulosics; however, its principal specific use is for dispersion of polyvinylidene fluoride (PVDF). PVDF is resistant to most chemicals and finds use as electrical insulation, chemical process equipment (particularly pipe), and as a case for long-life finishes for exterior metal siding. Coil coating techniques are used to apply PVDF dispersions to aluminum or galvanized steel siding.

For the protection of human health from the toxic properties of dimethyl phthalate ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 313 mg/l. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the ambient water criterion is 2,900 mg/l.

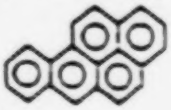
Based on limited data and observations relating molecular structure to ease of biochemical degradation of other toxic organic pollutants, it is expected that dimethyl phthalate will be biochemically oxidized to a lesser extent than domestic sewage by biological treatment in a POTW.

Polynuclear Aromatic Hydrocarbons (72-84). The polynuclear aromatic hydrocarbons (PAH) selected as toxic pollutants are a group of 13 compounds consisting of substituted and unsubstituted polycyclic aromatic rings. The general class of PAH includes heterocyclics, but none of those were selected as toxic pollutants. PAH are formed as the result of incomplete combustion when organic compounds are burned with insufficient oxygen. PAH are found in coke oven emissions, vehicular emissions, and volatile products of oil and gas burning. The compounds chosen as toxic pollutants are listed with their structural formula and melting point (m.p.). All are relatively insoluble in water.

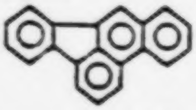
72 **Benzo(a)anthracene (1,2-benzanthracene)** **m.p. 162°C**



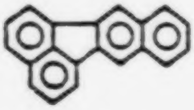
73 **Benzo(a)pyrene (3,4-benzopyrene)** **m.p. 176°C**



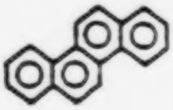
74 **3,4-Benzofluoranthene** **m.p. 168°C**



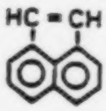
75 **Benzo(k)fluoranthene (11,12-benzofluoranthene)**
m.p. 217°C



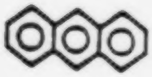
76 **Chrysene (1,2-benzphenanthrene)** **m.p. 255°C**



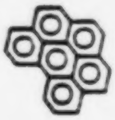
77 **Acenaphthylene** **m.p. 92°C**



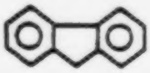
78 Anthracene m.p. 216°C



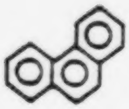
79 Benzo(ghi)perylene (1,12-benzoperylene) m.p. not reported



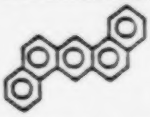
80 Fluorene (alpha-diphenylenemethane) m.p. 116°C



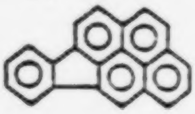
81 Phenanthrene m.p. 101°C



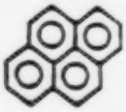
82 Dibenzo(a,h)anthracene (1,2,5,6-dibenzoanthracene) m.p. 269°C



83 Indeno (1,2,3-cd)pyrene (2,3-o-phenylenepyrene) m.p. not available



84 Pyrene m.p. 156°C



Some of these toxic pollutants have commercial or industrial uses. Benzo(a)anthracene, benzo(a)pyrene, chrysene, anthracene, dibenzo(a,h)anthracene, and pyrene are all used as antioxidants. Chrysene, acenaphthylene, anthracene, fluorene, phenanthrene, and pyrene are all used for synthesis of dyestuffs or other organic chemicals. 3,4-Benzofluoranthrene, benzo(k)fluoranthene, benzo(ghi)perylene, and indeno (1,2,3-cd)pyrene have no known industrial uses, according to the results of a recent literature search.

Several of the PAH toxic pollutants are found in smoked meats, in smoke flavoring mixtures, in vegetable oils, and in coffee.

Consequently, they are also found in many drinking water supplies. The wide distribution of these pollutants in complex mixtures with the many other PAHs which have not been designated as toxic pollutants results in exposures by humans that cannot be associated with specific individual compounds.

The screening and verification analysis procedures used for the toxic organic pollutants are based on gas chromatography (GC). Three pairs of the PAH have identical elution times on the column specified in the protocol, which means that the parameters of the pair are not differentiated. For these three pairs [anthracene (78) - phenanthrene (81); 3,4-benzofluoranthene (74) - benzo(k)-fluoranthene (75); and benzo(a)anthracene (72) - chrysene (76)] results are obtained and reported as "either-or." Either both are present in the combined concentration reported, or one is present in the concentration reported.

There are no studies to document the possible carcinogenic risks to humans by direct ingestion. Air pollution studies indicate an excess of lung cancer mortality among workers exposed to large amounts of PAH containing materials such as coal gas, tars, and coke-oven emissions. However, no definite proof exists that the PAH present in these materials are responsible for the cancers observed.

Animal studies have demonstrated the toxicity of PAH by oral and dermal administration. The carcinogenicity of PAH has been traced to formation of PAH metabolites which, in turn, lead to tumor formation. Because the levels of PAH which induce cancer are very low, little work has been done on other health hazards resulting from exposure. It has been established in animal studies that tissue damage and systemic toxicity can result from exposure to non-carcinogenic PAH compounds.

Because there were no studies available regarding chronic oral exposures to PAH mixtures, proposed water quality criteria were derived using data on exposure to a single compound. Two studies were selected, one involving benzo(a)pyrene ingestion and one involving dibenzo(a,h)anthracene ingestion. Both are known animal carcinogens.

For the maximum protection of human health from the potential carcinogenic effects of expsure to polynuclear aromatic hydrocarbons (PAH) through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of PAH estimated to result in additional risk of 1 in 100,000 were derived by the EPA and the Agency is considering setting criteria at an interim target risk level in the range of 10^{-7}, 10^{-6}, or 10^{-5} with corresponding criteria of 0.097 ng/l, 0.97 ng/l, and 9.7 ng/l, respectively.

No standard toxicity tests have been reported for freshwater or saltwater organisms and any of the 13 PAH discussed here.

The behavior of PAH in a POTW has received only a limited amount of study. It is reported that up to 90 percent of PAH entering a POTW will be retained in the sludge generated by conventional sewage treatment processes. Some of the PAH can inhibit bacterial growth when they are present at concentrations as low as 0.018 mg/l. Biological treatment in activated sludge units has been shown to reduce the concentration of phenanthrene and anthracene to some extent; however, a study of biochemical oxidation of fluorene on a laboratory scale showed no degradation after 5, 10, and 20 days. On the basis of that study and studies of other toxic organic pollutants, some general observations were made relating molecular structure to ease of degradation. Those observations lead to the conclusion that the 13 PAH selected to represent that group as toxic pollutants will be removed only slightly or not at all by biological treatment methods in a POTW. Based on their water insolubility and tendency to attach to sediment particles very little pass through of PAH to POTW effluent is expected. Sludge contamination is the likely environmental fate, although no data are available at this time to support any conclusions about contamination of land by PAH on which sewage sludge containing PAH is spread.

Tetrachloroethylene (85). Tetrachloroethylene (CCl_2CCl_2), also called perchloroethylene and PCE, is a colorless, nonflammable liquid produced mainly by two methods - chlorination and pyrolysis of ethane and propane, and oxychlorination of dichloroethane. U.S. annual production exceeds 300,000 tons. PCE boils at 121°C and has a vapor pressure of 19 mm Hg at 20°C. It is insoluble in water but soluble in organic solvents.

Approximately two-thirds of the U.S. production of PCE is used for dry cleaning. Textile processing and metal degreasing, in equal amounts consume about one-quarter of the U.S. production.

The principal toxic effect of PCE on humans is central nervous system depression when the compound is inhaled. Headache, fatigue, sleepiness, dizziness, and sensations of intoxication are reported. Severity of effects increases with vapor concentration. High integrated exposure (concentration times duration) produces kidney and liver damage. Very limited data on PCE ingested by laboratory animals indicate liver damage occurs when PCE is administered by that route. PCE tends to distribute to fat in mammalian bodies.

One report found in the literature suggests, but does not conclude, that PCE is teratogenic. PCE has been demonstrated to be a liver carcinogen in B6C3-F1 mice.

For the maximum protection of human health from the potential carcinogenic effects of exposure to tetrachlorethylene through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of tetrachloroethylene estimated to result in additional lifetime cancer risk levels of 10^{-7}, 10^{-6}, and 10^{-5} are 0.02 ug/l, 0.2 ug/l, and 2 ug/l, respectively.

No data were found regarding the behavior of PCE in a POTW. Many of the toxic organic pollutants have been investigated, at least in laboratory scale studies, at concentrations higher than those expected to be contained by most municipal wastewaters. General observations have been developed relating molecular structure to ease of degradation for all of the toxic organic pollutants. The conclusions reached by the study of the limited data is that biological treatment produces a moderate removal of PCE in a POTW by degradation. No information was found to indicate that PCE accumulates in the sludge, but some PCE is expected to be adsorbed onto settling particles. Some PCE is expected to be volatilized in aerobic treatment processes and little, if any, is expected to pass through into the effluent from the POTW.

Toluene (86). Toluene is a clear, colorless liquid with a benzene-like odor. It is a naturally occuring compound derived primarily from petroleum or petrochemical processes. Some toluene is obtained from the manufacture of metallurgical coke. Toluene is also referred to as totuol, methylbenzene, methacide, and phenylmethane. It is an aromatic hydrocarbon with the formula $C_6H_5CH_3$. It boils at 111°C and has a vapor pressure of 30 mm Hg at room temperature. The water solubility of toluene is 535 mg/l, and it is miscible with a variety of organic solvents. Annual production of toluene in the U.S. is greater than two million metric tons. Approximately two-thirds of the toluene is converted to benzene and the remaining 30 percent is divided approximately equally into chemical manufacture, and use as a paint solvent and aviation gasoline additive. An estimated 5,000 metric tons is discharged to the environment anually as a constituent in wastewater.

Most data on the effects of toluene in human and other mammals have been based on inhalation exposure or dermal contact studies. There appear to be no reports of oral administration of toluene to human subjects. A long term toxicity study on female rats revealed no adverse effects on growth, mortality, appearance and behavior, organ to body weight ratios, blood-urea nitrogen levels, bone marrow counts, peripheral blood counts, or morphology of major organs. The effects of inhaled toluene on the central nervous system, both at high and low concentrations, have been studied in humans and animals. However, ingested toluene is expected to be handled differently by the body because it is absorbed more slowly and must first pass through the liver before reaching the nervous system. Toluene is extensively and rapidly metabolized in the liver. One of the principal metabolic products of toluene is benzoic acid, which itself seems to have little potential to produce tissue injury.

Toluene does not appear to be teratogenic in laboratory animals or man. Nor is there any conclusive evidence that toluene is mutagenic. Toluene has not been demonstrated to be positive in any *in vitro* mutagenicity or carcinogenicity bioassay system, nor to be carcinogenic in animals or man.

Toluene has been found in fish caught in harbor waters in the vicinity of petroleum and petrochemical plants. Bioconcentration studies have not been conducted, but bioconcentration factors have been calculated on the basis of the octanol-water partition coefficient.

For the protection of human health from the toxic properties of toluene ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 14.3 mg/l. If contaminated aquatic organisms alone are consumed excluding the consumption of water, the ambient water criterion is 424 mg/l. Available data show that the adverse effects on aquatic life occur at concentrations as low as 5 mg/l.

Acute toxicity tests have been conducted with toluene and a variety of freshwater fish and *Daphnia magna*. The latter appears to be significantly more resistant than fish. No test results have been reported for the chronic effects of toluene on freshwater fish or invertebrate species.

No detailed study of toluene behavior in a POTW is available. However, the biochemical oxidation of many of the toxic pollutants has been investigated in laboratory scale studies at concentrations greater than those expected to be contained by most municipal wastewaters. At toluene concentrations ranging from 3 to 250 mg/l biochemical oxidation proceeded to 50 percent of theoretical or greater. The time period varied from a few hours to 20 days depending on whether or not the seed culture was acclimated. Phenol adapted acclimated seed cultures gave the most rapid and extensive biochemical oxidation.

Based on study of the limited data, it is expected that toluene will be biochemically oxidized to a lesser extent than domestic sewage by biological treatment in a POTW. The volatility and relatively low water solubility of toluene lead to the expectation that aeration processes will remove significant quantities of toluene from the POTW. The EPA studied toluene removal in seven POTW facilities. The removals ranged from 40 to 100 percent. Sludge concentrations of toluene ranged from 54×10^{-3} to 1.85 mg/l.

Trichloroethylene (87). Trichloroethylene (1,1,2-trichloroethylene or TCE) is a clear, colorless liquid boiling at 87°C. It has a vapor pressure of 77 mm Hg at room temperature and is slightly soluble in water (1 gm/l). U.S. production is greater than 0.25 million metric tons annually. It is produced from tetrachloroethane by treatment with lime in the presence of water.

TCE is used for vapor phase degreasing of metal parts, cleaning and drying electronic components, as a solvent for paints, as a refrigerant, for extraction of oils, fats, and waxes, and for dry cleaning. Its widespread use and relatively high volatility result in detectable levels in many parts of the environment.

Data on the effects produced by ingested TCE are limited. Most studies have been directed at inhalation exposure. Nervous system disorders and liver damage are frequent results of inhalation exposure. In the short term exposures, TCE acts as a central nervous system depressant - it was used as an anesthetic before its other long term effects were defined.

TCE has been shown to induce transformation in a highly sensitive *in vitro* Fischer rat embryo cell system (F1706) that is used for identifying carcinogens. Severe and persistent toxicity to the liver was recently demonstrated when TCE was shown to produce carcinoma of the liver in mouse strain B6C3F1. One systematic study of TCE exposure and the incidence of human cancer was based on 518 men exposed to TCE. The authors of that study concluded that although the cancer risk to man cannot be ruled out, exposure to low levels of TCE probably does not present a very serious and general cancer hazard.

TCE is bioconcentrated in aquatic species, making the consumption of such species by humans a significant source of TCE. For the protection of human health from the potential carcinogenic effects of exposure to trichloroethylene through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of trichloroethylene estimated to result in additional lifetime cancer risks of 10^{-7}, 10^{-6}, and 10^{-5} are 0.27 ug/l, 2.7 ug/l, and 27 ug/l, respectively. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the water concentration should be less than 0.807 mg/l to keep the additional lifetime cancer risk below 10^{-5}.

Only a very limited amount of data on the effects of TCE on freshwater aquatic life are available. One species of fish (fathead minnows) showed a loss of equilibrium at concentrations below those resulting in lethal effects.

The behavior of trichloroethylene in a POTW has not been studied. However, in laboratory scale studies of toxic organic pollutants, TCE was subjected to biochemical oxidation conditions. After 5, 10, and 20 days no biochemical oxidation occurred. On the basis of this study and general observations relating molecular structure to ease of degradation, the conclusion is reached that TCE would undergo no removal by biological treatment in a POTW. The volatility and relatively low water solubility of TCE is expected to result in volatilization of some of the TCE in aeration steps in a POTW.

Polychlorinated Biphenyls (106 - 112). Polychlorinated biphenyls ($C_{12}H_{10}nCl_n,H_{10}$-nCl_n where n can range from 1 to 10), designated PCB's, are chlorinated derivatives of biphenyls. The commercial products are complex mixtures of chlorobiphenyls, but are no longer produced in the U.S. The mixtures produced formerly were characterized by the percentage chlorination. Direct chlorination of biphenyl was used to produce mixtures containing from 21 to 70 percent chlorine. Seven of these mixtures have been selected as toxic pollutants:

Toxic Pollutant No.	Name	Percent Chlorine	Range (°C) Distillation	Pour Point (°C)	Water Solubility
	Arochlor				
106	1242	42	325-366	-19	240
107	1254	54	365-390	10	12
108	1221	20.5-21.5	275-320	1	<200
109	1232	31.4-32.5	290-325	-35.5	--
110	1248	48	340-375	- 7	54
111	1260	60	385-420	31	2.7
112	1016	41	323-356	--	225-250

The arochlors 1221, 1232, 1016, 1242, and 1248 are colorless, oily liquids; 1254 is a viscous liquid; 1260 is a sticky resin at room temperature. Total annual U.S. production of PCB's averaged about 20,000 tons in 1972 to 1974.

Prior to 1971, PCB's were used in several applications including plasticizers, heat transfer liquids, hydraulic fluids, lubricants, vacuum pump and compressor fluids, and capacitor and transformer oils. After 1970, when PCB use was restricted to closed systems, the latter two uses were the only commercial applications.

The toxic effects of PCB's ingested by humans have been reported to range from acne-like skin eruptions and pigmentation of the skin to numbness of limbs, hearing and vision problems, and spasms. Interpretation of results is complicated by the fact that the very highly toxic polychlorinated dibenzofurans (PCDF's) are found in many commercial PCB mixtures. Photochemical and thermal decomposition appear to accelerate the transformation of PCB's to PCDF's. Thus the specific effects of PCB's may be masked by the effects of PCDF's. However, if PCDF's are frequently present to some extent in any PCB mixture, then their effects may be properly included in the effects of PCB mixtures.

Studies of effects of PCB's in laboratory animals indicate that liver and kidney damage, large weight losses, eye discharges, and interference with some metabolic processes occur frequently. Teratogenic effects of PCB's in laboratory animals have been observed, but are rare. Growth retardations during gestation, and reproductive failure are more common effects observed in studies of PCB teratogenicity. Carcinogenic effects of PCB's have been studied in laboratory animals with results interpreted as positive. Specific reference has been made to liver cancer in rats in the discussion of water quality criterion formulation.

For the maximum protection of human health from the potential carcinogenic effects of exposure to PCB's through ingestion of water and contaminated aquatic organisms, the ambient water concentration should be zero. Concentrations of PCB's estimated to result in additional lifetime cancer risk at risk levels of 10^{-7}, 10^{-6}, and 10^{-5} are 0.0026 ng/l, 0.026 ng/l, and 0.26 ng/l, respectively.

The behavior of PCB's in a POTW has received limited study. Most PCB's will be removed with sludge. One study showed removals of 82 to 89 percent, depending on suspended solid removal. The PCB's adsorb onto suspended sediments and other particulates. In laboratory scale experiments with PCB 1221, 81 percent was removed by degradation in an activated sludge system in 47 hours. Biodegradation can form polychlorinated dibenzofurans which are more toxic than PCB's (as noted earlier). PCB's at concentrations of 0.1 to 1,000 mg/l inhibit or enhance bacterial growth rates, depending on the bacterial culture and the percentage chlorine in the PCB. Thus, activated sludge may be inhibited by PCB's. Based on studies of bioaccumulation of PCB's in food crops grown on soils amended with PCB-containing sludge, the U.S. FDA has recommended a limit of 10 mg PCB/kg dry weight of sludge used for application to soils bearing food crops.

Antimony (114). Antimony (chemical name - stibium, symbol Sb), classified as a non-metal or metalloid, is a silvery white, brittle crystalline solid. Antimony is found in small ore bodies throughout the world. Principal ores are oxides of mixed antimony valences, and an oxysulfide ore. Complex ores with metals are important because the antimony is recovered as a by-product. Antimony melts at 631°C, and is a poor conductor of electricity and heat.

Annual U.S. consumption of primary antimony ranges from 10,000 to 20,000 tons. About half is consumed in metal products - mostly antimonial lead for lead acid storage batteries, and about half in non-metal products. A principal compound is antimony trioxide which is used as a flame retardant in fabrics, and as an opacifier in glass, ceramics, and enamels. Several antimony compounds are used as catalysts in organic chemicals synthesis, as fluorinating agents (the antimony fluoride), as pigments, and in fireworks. Semiconductor applications are economically significant.

Essentially no information on antimony-induced human health effects has been derived from community epidemiology studies. The available data are in literature relating effects observed with therapeutic or medicinal uses of antimony compounds and industrial exposure studies. Large therapeutic doses of antimonial compounds, usually used to treat schistisomiasis, have caused severe nausea, vomiting, convulsions, irregular heart action, liver damage, and skin rashes. Studies of acute industrial antimony poisoning have revealed loss of appetite, diarrhea, headache, and dizziness in addition to the symptoms found in studies of therapeutic doses of antimony.

For the protection of human health from the toxic properties of antimony ingested through water and through contaminated aquatic organisms the ambient water criterion is determined to be 0.146 mg/l. If contaminated aquatic organisms are consumed, excluding the consumption of water, the ambient water criterion is determined to be 45 mg/l. Available data show that adverse effects on aquatic life occur at concentrations higher than those cited for human health risks.

Very little information is available regarding the behavior of antimony in a POTW. The limited solubility of most antimony compounds expected in a POTW, i.e., the oxides and sulfides, suggests that at least part of the antimony entering a POTW will be precipitated and incorporated into the sludge. However, some antimony is expected to remain dissolved and pass through the POTW into the effluent. Antimony compounds remaining in the sludge under anaerobic conditions may be connected to stibine (SbH_3), a very soluble and very toxic compound. There are no data to show antimony inhibits any POTW processes. Antimony is not known to be essential to the growth of plants, and has been reported to be moderately toxic. Therefore, sludge containing large amounts of antimony could be detrimental to plants if it is applied in large amounts to cropland.

Arsenic (115). Arsenic (chemical symbol As), is classified as a non-metal or metalloid. Elemental arsenic normally exists in the alpha-crystalline metallic form which is steel gray and brittle, and in the beta form which is dark gray and amorphous. Arsenic sublimes at 615°C. Arsenic is widely distributed throughout the world in a large number of minerals. The most important commercial source of arsenic is as a by-product from treatment of copper, lead, cobalt, and gold ores. Arsenic is usually marketed as the trioxide (As_2O_3). Annual U.S. production of the trioxide approaches 40,000 tons.

The principal use of arsenic is in agricultural chemicals (herbicides) for controlling weeds in cotton fields. Arsenicals have various applications in medicinal and vetrinary use, as wood preservatives, and in semiconductors.

The effects of arsenic in humans were known by the ancient Greeks and Romans. The principal toxic effects are gastrointestinal disturbances. Breakdown of red blood cells occurs. Symptoms of acute poisoning include vomiting, diarrhea, abdominal pain, lassitude, dizziness, and headache. Longer exposure produced dry, falling hair, brittle, loose nails, eczema, and exfoliation. Arsenicals also exhibit teratogenic and mutagenic effects in humans. Oral administration of arsenic compounds has been associated clinically with skin cancer for nearly one hundred years. Since 1888 numerous studies have linked occupational exposure and therapeutic administration of arsenic compounds to increased incidence of respiratory and skin cancer.

For the maximum protection of human health from the potential carcinogenic effects of exposure to arsenic through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of arsenic estimated to result in additional lifetime cancer risk levels of 10^{-7}, 10^{-6}, and 10^{-5} are 2.2×10^{-7} mg/l, 2.2×10^{-6} mg/l, and 2.2×10^{-5} mg/l, respectively. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the water concentration should be less than 1.75×10^{-4} to keep the increased lifetime cancer risk below 10^{-5}. Available data show that adverse effects on aquatic life occur at concentrations higher than those cited for human health risks.

A few studies have been made regarding the behavior of arsenic in a POTW. One EPA survey of nine POTW facilities reported influent concentrations ranging from 0.0005 to 0.693 mg/l; effluents from three a POTW having biological treatment contained 0.0004 to 0.01 mg/l; two POTW facilities showed arsenic removal efficiencies of 50 and 71 percent in biological treatment. Inhibition of treatment processes by sodium arsenate is reported to occur at 0.1 mg/l in activated sludge, and 1.6 mg/l in anaerobic digestion processes. In another study based on data from 60 POTW facilities, arsenic in sludge ranged from 1.6 to 65.6 mg/kg and the median value was 7.8 mg/kg. Arsenic in sludge spread on cropland may be taken up by plants grown on that land. Edible plants can take up arsenic, but normally their growth is inhibited before the plants are ready for harvest.

Asbestos (116). Asbestos is a generic term used to describe a group of hydrated mineral silicates that can appear in a fibrous crystal form (asbestiform) and, when crushed, can separate into flexible fibers. The types of asbestos presently used commercially fall into two mineral groups: the sepentine and amphibole groups. Asbestos is minerologically stable and is not prone to significant chemical or biological degradation in the aquatic environment. In 1978, the total consumption of asbestos in the U.S. was 583,000 metric tons. Asbestos is an excellent insulating material and is used in a wide variety of products. Based on 1975 figures, the total annual identifiable asbestos emissions are estimated at 243,527 metric tons. Land discharges account for 98.3 percent of the emissions, air discharges account for 1.5 percent, and water discharges account for 0.2 percent.

Asbestos has been found to produce significant incidence of disease among workers occupationally exposed in mining and milling, in manufacturing, and in the use of materials containing the fiber. The predominant type of exposure has been inhalation, although some asbestos may be swallowed directly or ingested after being expectorated from the respiratory tract. Noncancerous asbestos disease has been found among people directly exposed to high levels of asbestos as a result of excessive work exposure; much less frequently, amongh those with lesser exposures although there is extensive evidence of pulmonary disease among people exposed to airborne asbestos. There is little evidence of disease among people exposed to waterborne fibers.

Asbestos at the concentrations currently found in the aquatic environment does not appear to exert toxic effects on aquatic organisms. For the maximum protection of human health from the potential carcinogenic effects of exposure to asbestos through ingestion of water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption of this substance. However, zero level may not be attainable at the present time. Therefore, levels which may result in incremental increase of cancer risk over the life time are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding recommended criteria are 300,000 fibers/l, 30,000 fibers/l, and 3,000 fibers/l.

The available data indicate that technologies used at POTW for reducing levels of total suspended solids in wastewater also provide a concomitant reduction in asbestos levels. Asbestos removal efficiencies ranging from 80 percent to greater than 99 percent have been reported following sedimentation of wastewater. Filtration and sedimentation with chemical addition (i.e., lime and/or polymer) have achieved even greater percentage removals.

Beryllium (117). Beryllium is a dark gray metal of the alkaline earth family. It is relatively rare, but because of its unique properties finds widespread use as an alloying element, especially for hardening copper which is used in springs, electrical contacts, and non-sparking tools. World production is reported to be in the range of 250 tons annually. However, much more reaches the environment as emissions from coal burning operations. Analysis of coal indicates an average beryllium content of 3 ppm and 0.1 to 1.0 percent in coal ash or fly ash.

The principal ores are beryl ($3BeO.Al_2O_3.6SiO_2$) and bertrandite [$Be_4Si_2O_7(OH)_2$]. Only two industrial facilities produce beryllium in the U.S. because of limited demand and the highly toxic character. About two-thirds of the annual production goes into alloys, 20 percent into heat sinks, and 10 percent into beryllium oxide (BeO) ceramic products.

Beryllium has a specific gravity of 1.846, making it the lightest metal with a high melting point (1,350°C). Beryllium alloys are corrosion resistant, but the metal corrodes in aqueous environments. Most common beryllium compounds are soluble in water, at least to the extent necessary to produce a toxic concentration of beryllium ions.

Most data on toxicity of beryllium is for inhalation of beryllium oxide dust. Some studies on orally administered beryllium in laboratory animals have been reported. Despite the large number of studies implicating beryllium as a carcinogen, there is no recorded instance of cancer being produced by ingestion. However, a recently convened panel of uninvolved experts concluded that epidemiologic evidence is suggestive that beryllium is a carcinogen in man.

In the aquatic environment beryllium is chronically toxic to aquatic organisms at 0.0053 mg/l. Water softness has a large effect on beryllium toxicity to fish. In soft water, beryllium is reportedly 100 times as toxic as in hard water.

For the maximum protection of human health from the potential carcinogenic effects of exposure to beryllium through ingestion of water and contaminated aquatic organisms the ambient water concentration is zero. Concentrations of beryllium estimated to result in additional lifetime cancer risk levels of 10^{-7}, 10^{-6}, and 10^{-5} are 0.68 ng/l, 6.8 ng/l, and 68 ng/l, respectively. If contaminated aquatic organisms alone are consumed excluding the consumption of water, the concentration should be less than 0.00117 mg/l to keep the increased lifetime cancer risk below 10^{-5}.

Information on the behavior of beryllium in a POTW is scarce. Because beryllium hydroxide is insoluble in water, most beryllium entering a POTW will probably be in the form of suspended solids. As a result most of the beryllium will settle and be removed with sludge. However, beryllium has been shown to inhibit several enzyme systems, to interfere with DNA metabolism in liver, and to induce chromosomal and mitotic abnormalities. This intereference in cellular processes may extend to interfere with biological treatment processes. The concentration and effects of beryllium in sludge which could be applied to cropland has not been studied.

Cadmium (118). Cadmium is a relatively rare metallic element that is seldom found in sufficient quantities in a pure state to warrant mining or extraction from the earth's surface. It is found in trace amounts of about 1 ppm throughout the earth's crust. Cadmium is, however, a valuable by-product of zinc production.

Cadmium is used primarily as an electroplated metal, and is found as an impurity in the secondary refining of zinc, lead, and copper.

Cadmium is an extremely dangerous cumulative toxicant, causing progressive chronic poisoning in mammals, fish, and probably other organisms. The metal is not excreted.

Toxic effects of cadmium on man have been reported from throughout the world. Cadmium may be a factor in the development of such human pathological conditions as kidney disease, testicular tumors, hypertension, arteriosclerosis, growth inhibition, chronic disease of old age, and cancer. Cadmium is normally ingested by humans through food and water as well as by breathing air contaminated by cadmium dust. Cadmium is cumulative in the liver, kidney, pancreas, and thyroid of humans and other animals. A severe bone and kidney syndrome known as itai-itai disease has been documented in Japan as caused by cadmium ingestion via drinking water and contaminated irrigation water. Ingestion of as little as 0.6 mg/day has produced the disease. Cadmium acts synergistically with other metals. Copper and zinc substantially increase its toxicity.

Cadmium is concentrated by marine organisms, particularly molluscs, which accumulate cadmium in calcareous tissues and in the viscera. A concentration factor of 1,000 for cadmium in fish muscle has been reported, as have concentration factors of 3,000 in marine plants and up to 29,600 in certain marine animals. The eggs and larvae of fish are apparently more sensitive than adult fish to poisoning by cadmium, and crustaceans appear to be more sensitive than fish eggs and larvae.

For the protection of human health from the toxic properties of cadmium ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 0.010 mg/l. Available data show that adverse effects on aquatic life occur at concentrations in the same range as those cited for human health, and they are highly dependent on water hardness.

Cadmium is not destroyed when it is introduced into a POTW, and will either pass through to the POTW effluent or be incorporated into the POTW sludge. In addition, it can interfere with the POTW treatment process.

In a study of 189 POTW facilities, 75 percent of the primary plants, 57 percent of the trickling filter plants, 66 percent of the activated sludge plants, and 62 percent of the biological plants allowed over 90 percent of the influent cadmium to pass through to the POTW effluent. Only two of the 189 POTW facilities allowed less than 20 percent pass-through, and none less than 10 percent pass-through. POTW effluent concentrations ranged from 0.001 to 1.97 mg/l (mean 0.028 mg/l, standard deviation 0.167 mg/l).

Cadmium not passed through the POTW will be retained in the sludge where it is likely to build up in concentration. Cadmium contamination of sewage sludge limits its use on land since it increases the level of cadmium in the soil. Data show that cadmium can be incorporated into crops, including vegetables and grains, from contaminated soils. Since the crops themselves show no adverse effects from soils with levels up to 100 mg/kg cadmium, these contaminated crops could have a significant impact on human health. Two Federal agencies have already recognized the potential adverse human health effects posed by the use of sludge on cropland. The FDA recommends that sludge containing over 30 mg/kg of cadmium should not be used on agricultural land. Sewage sludge contains 3 to 300 mg/kg (dry basis) of cadmium mean = 10 mg/kg; median = 16 mg/kg. The USDA also recommends placing limits on the total cadmium from sludge that may be applied to land.

Chromium (119). Chromium is an elemental metal usually found as a chromite ($FeO.Cr_2O_3$). The metal is normally produced by reducing the oxide with aluminum. A significant proportion of the chromium used is in the form of compounds such as sodium dichromate (Na_2CrO_4), and chromic acid (CrO_3) - both are hexavalent chromium compounds.

Chromium is found as an alloying component of many steels and its compounds are used in electroplating baths, and as corrosion inhibitors for closed water circulation systems.

The two chromium forms most frequently found in industry wastewaters are hexavalent and trivalent chromium. Hexavalent chromium is the form used for metal treatments. Some of it is reduced to trivalent chromium as part of the process reaction. The raw wastewater containing both valence states is usually treated first to reduce remaining hexavalent to trivalent chromium, and second to precipitate the trivalent form as the hydroxide. The hexavalent form is not removed by lime treatment.

Chromium, in its various valence states, is hazardous to man. It can produce lung tumors when inhaled, and induces skin sensitizations. Large doses of chromates have corrosive effects on the intestinal tract and can cause inflammation of the kidneys. Hexavalent chromium is a known human carcinogen. Levels of chromate ions that show no effect in man appear to be so low as to prohibit determination, to date.

The toxicity of chromium salts to fish and other aquatic life varies widely with the species, temperature, pH, valence of the chromium, and synergistic or antagonistic effects, especially the effect of water hardness. Studies have shown that trivalent chromium is more toxic to fish of some types than is hexavalent chromium. Hexavalent chromium retards growth of one fish species at 0.0002 mg/l. Fish food organisms and other lower forms of aquatic life are extremely sensitive to chromium. Therefore, both hexavalent and trivalent chromium must be considered harmful to particular fish or organisms.

For the protection of human health from the toxic properties of chromium (except hexavalent chromium) ingested through water and contaminated aquatic organisms, the ambient water quality criterion is 170 mg/l. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the ambient water criterion for trivalent chromium is 3,443 mg/l. The ambient water quality criterion for hexavalent chromium is recommended to be identical to the existing drinking water standard for total chromium which is 0.050 mg/l.

Chromium is not destroyed when treated by a POTW (although the oxidation state may change), and will either pass through to the POTW effluent or be incorporated into the POTW sludge. Both oxidation states can cause POTW treatment inhibition and can also limit the usefulness of municipal sludge.

Influent concentrations of chromium to POTW facilities have been observed by EPA to range from 0.005 to 14.0 mg/l, with a median concentration of 0.1 mg/l. The efficiencies for removal of chromium by the activated sludge process can vary greatly, depending on chromium concentration in the influent, and other operating conditions at the POTW. Chelation of chromium by organic matter and dissolution due to the presence of carbonates can cause deviations from the predicted behavior in treatment systems.

The systematic presence of chromium compounds will halt nitrification in a POTW for short periods, and most of the chromium will be retained in the sludge solids. Hexavalent chromium has been reported to severely affect the nitrification process, but trivalent chromium has little or no toxicity to activated sludge, except at high concentrations. The presence of iron, copper, and low pH will increase the toxicity of chromium in a POTW by releasing the chromium into solution to be ingested by microorganisms in the POTW.

The amount of chromium which passes through to the POTW effluent depends on the type of treatment processes used by the POTW. In a study of 240 POTW facilities, 56 percent of the primary plants allowed more than 80 percent pass-through to POTW effluent. More advanced treatment results in less pass-through. POTW effluent concentrations ranged from 0.003 to 3.2 mg/l total chromium (mean = 0.197, standard deviation = 0.48), and from 0.002 to 0.1 mg/l hexavalent chromium (mean = 0.017, standard deviation = 0.020).

Chromium not passed through the POTW will be retained in the sludge, where it is likely to build up in concentration. Sludge concentrations of total chromium of over 20,000 mg/kg (dry basis) have been observed. Disposal of sludges containing very high concentrations of trivalent chromium can potentially cause problems in uncontrolled landfills. Incineration, or similar destructive oxidation processes, can produce hexavalent chromium from lower valence states. Hexavalent chromium is potentially more toxic than trivalent chromium. In cases where high rates of chrome sludge application on land are used, distinct growth inhibition and plant tissue uptake have been noted.

Pretreatment of discharges substantially reduces the concentration of chromium in sludge. In Buffalo, New York, pretreatment of electroplating waste resulted in a decrease in chromium concentrations in POTW sludge from 2,510 to 1,040 mg/kg. A similar reduction occurred in Grand Rapids, Michigan, POTW facilities where the chromium concentration in sludge decreased from 11,000 to 2,700 mg/kg when pretreatment was made a requirement.

Copper (120). Copper is a metallic element that sometimes is found free, as the native metal, and is also found in minerals such as cuprite (Cu_2O), malechite [$CuCO_3.Cu(OH)_2$], azurite [$2CuCO_3.Cu(OH)_2$], chalcopyrite ($CuFeS_2$), and bornite (Cu_5FeS_4). Copper is obtained from these ores by smelting, leaching, and electrolysis. It is used in the plating, electrical, plumbing, and heating equipment industries, as well as in insecticides and fungicides.

Traces of copper are found in all forms of plant and animal life, and the metal is an essential trace element for nutrition. Copper is not considered to be a cumulative systemic poison for humans as it is readily excreted by the body, but it can cause symptoms of gastroenteritis, with nausea and intestinal irritations, as relatively low dosages. The limiting factor in domestic water supplies is taste. To prevent this adverse organoleptic effect of copper in water, a criterion of 1 mg/l has been established.

The toxicity of copper to aquatic organisms varies significantly, not only with the species, but also with the physical and chemical characteristics of the water, including temperature, hardness, turbidity, and carbon dioxide content. In hard water, the toxicity of copper salts may be reduced by the precipitation of copper carbonate or other insoluble compounds. The sulfates of copper and zinc, and of copper and calcium are synergistic in their toxic effect on fish.

Relatively high concentrations of copper may be tolerated by adult fish for short periods of time; the critical effect of copper appears to be its higher toxicity to young or juvenile fish. Concentrations of 0.02 to 0.03 mg/l have proved fatal to some common fish species. In general the salmonoids are very sensitive and the sunfishes are less sensitive to copper.

The recommended criterion to protect freshwater aquatic life is 0.0056 mg/l as a 24-hour average, and 0.012 mg/l maximum concentration at a hardness of 50 mg/l $CaCO_3$. For total recoverable copper the criterion to protect freshwater aquatic life is 0.0056 mg/l as a 24-hour average.

Copper salts cause undesirable color reactions in the food industry and cause pitting when deposited on some other metals such as aluminum and galvanized steel. To control undesirable taste and odor quality of ambient water due to the organoleptic properties of copper, the estimated level is 1.0 mg/l for total recoverable copper.

Irrigation water containing more than minute quantities of copper can be detrimental to certain crops. Copper appears in all soils, and its concentration ranges from 10 to 80 ppm. In soils, copper occurs in association with hydrous oxides of manganese and iron, and also as soluble and insoluble complexes with organic matter. Copper is essential to the life of plants, and the normal range of concentration in plant tissue is from 5 to 20 ppm. Copper concentrations in plants normally do not build up to high levels when toxicity occurs. For example, the concentrations of copper in snapbean leaves and pods was less than 50 and 20 mg/kg, respectively, under conditions of severe copper toxicity. Even under conditions of copper toxicity, most of the excess copper accumulates in the roots; very little is moved to the aerial part of the plant.

Copper is not destroyed when treated by a POTW, and will either pass through to the POTW effluent or be retained in the POTW sludge. It can interfere with the POTW treatment processes and can limit the usefulness of municipal sludge.

The influent concentration of copper to a POTW has been observed by the EPA to range from 0.01 to 1.97 mg/l, with a median concentration of 0.12 mg/l. The copper that is removed from the influent stream of a POTW is absorbed on the sludge or appears in the sludge as the hydroxide of the metal. Bench scale pilot studies have shown that from about 25 percent to 75 percent of the copper passing through the activated sludge process remains in solution in the final effluent. Four-hour slug dosages of copper sulfate in concentrations exceeding 50 mg/l were reported to have severe effects on the removal efficiency of an unacclimated system, with the system returning to normal in about 100 hours. Slug dosages of copper in the form of copper cyanide were observed to have much more severe effects on the activated sludge system, but the total system returned to normal in 24 hours.

In a recent study of 268 POTW facilities, the median pass-through was over 80 percent for primary plants and 40 to 50 percent for trickling filter, activated sludge, and biological treatment plants. POTW effluent concentrations of copper ranged from 0.003 to 1.8 mg/l (mean 0.126, standard deviation 0.242).

Copper which does not pass through the POTW will be retained in the sludge where it will build up in concentration. The presence of excessive levels of copper in sludge may limit its use on cropland. Sewage sludge contains up to 16,000 mg/kg of copper, with 730 mg/kg as the mean value. These concentrations are significantly greater than those normally found in soil, which usually range from 18 to 80 mg/kg. Experimental data indicate that when dried sludge is spread over tillable land, the copper tends to remain in place down to the depth of the tillage, except for copper which is taken up by plants grown in the soil. Recent investigation has shown that the extractable copper content of sludge-treated soil decreased with time, which suggests a reversion of copper to less soluble forms was occurring.

Cyanide (121). Cyanides are among the most toxic of pollutants commonly observed in industrial wastewaters. Introduction of cyanide into industrial processes is usually by dissolution of potassium cyanide (KCN) or sodium cyanide (NaCN) in process waters. However, hydrogen cyanide (HCN) formed when the above salts are dissolved in water, is probably the most acutely lethal compound.

The relationship of pH to hydrogen cyanide formation is very important. As pH is lowered to below 7, more than 99 percent of the cyanide is present as HCN and less than 1 percent as cyanide ions. Thus, at neutral pH, that of most living organisms, the more toxic form of cyanide prevails.

Cyanide ions combine with numerous heavy metal ions to form complexes. The complexes are in equilibrium with HCN. Thus, the stability of the metal-cyanide complex and the pH determine the concentration of HCN. Stability of the metal-cyanide anion complexes is extremely variable. Those formed with zinc, copper, and cadmium are not stable - they rapidly dissociate, with production of HCN, in near neutral or acid waters. Some of the complexes are extremely stable. Cobaltocyanide is very resistant to acid distillation in the laboratory. Iron cyanide complexes are also stable, but undergo photodecomposition to give HCN upon exposure to sunlight. Synergistic effects have been demonstrated for the metal cyanide complexes making zinc, copper, and cadmium cyanides more toxic than an equal concentration of sodium cyanide.

The toxic mechanism of cyanide is essentially an inhibition of oxygen metabolism, i.e., rendering the tissues incapable of exchanging oxygen. The cyanogen compounds are true noncumulative protoplasmic poisons. They arrest the activity of all forms of animal life. Cyanide shows a very specific type of toxic action. It inhibits the cytochrome oxidase system. This system is the one which facilitates electron transfer from reduced metabolites to molecular oxygen. The human body can convert cyanide to a non-toxic thiocyanate and eliminate it. However, if the quantity of cyanide ingested is too great at one time, the inhibition of oxygen utilization proves fatal before the detoxifying reaction reduces the cyanide concentration to a safe level.

Cyanides are more toxic to fish than to lower forms of aquatic organisms such as midge larvae, crustaceans, and mussels. Toxicity to fish is a function of chemical form and concentration, and is influenced by the rate of metabolism (temperature), the level of dissolved oxygen, and pH. In laboratory studies free cyanide concentrations ranging from 0.05 to 0.14 mg/l have been proven to be fatal to sensitive fish species including trout, bluegill, and fathead minnows. Levels above 0.2 mg/l are rapidly fatal to most fish species. Long term sublethal concentrations of cyanide as low as 0.01 mg/l have been shown to affect the ability of fish to function normally, e.g., reproduce, grow, and swim.

For the protection of human health from the toxic properties of cyanide ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 0.200 mg/l.

Persistence of cyanide in water is highly variable and depends upon the chemical form of cyanide in the water, the concentration of cyanide, and the nature of other constituents. Cyanide may be destroyed by strong oxidizing agents such as permanganate and chlorine. Chlorine is commonly used to oxidize strong cyanide solutions. Carbon dioxide and nitrogen are the products of complete oxidation. But if the reaction is not complete, the very toxic compound, cyanogen chloride, may remain in the treatment system and subsequently be released to the environment. Partial chlorination may occur as part of a POTW treatment, or during the disinfection treatment of surface water for drinking water preparation.

Cyanides can interfere with treatment processes in a POTW, or pass through to ambient waters. At low concentrations and with acclimated microflora, cyanide may be decomposed by microorganisms in anaerobic and aerobic environments or waste treatment systems. However, data indicate that much of the cyanide introduced passes through to the POTW effluent. The mean pass-through of 14 biological plants was 71 percent. In a recent study of 41 POTW facilities the effluent concentrations ranged from 0.002 to 100 mg/1 (mean = 2.518, standard deviation = 15.6). Cyanide also enhances the toxicity of metals commonly found in POTW effluents, including the toxic pollutants cadmium, zinc, and copper.

Data for Grand Rapids, Michigan, showed a significant decline in cyanide concentrations downstream from the POTW after pretreatment regulations were put in force. Concentrations fell from 0.66 mg/1 before, to 0.01 mg/1 after pretreatment was required.

Lead (122). Lead is a soft, malleable, ductile, blueish-gray, metallic element, usually obtained from the mineral galena (lead sulfide, PbS), anglesite (lead sulfate, $PbSO_4$), or cerussite (lead carbonate, $PbCO_3$). Because it is usually associated with minerals of zinc, silver, copper, gold, cadmium, antimony, and arsenic, special purification methods are frequently used before and after extraction of the metal from the ore concentrate by smelting.

Lead is widely used for its corrosion resistance, sound and vibration absorption, low melting point (solders), and relatively high imperviousness to various forms of radiation. Small amounts of copper, antimony and other metals can be alloyed with lead to achieve greater hardness, stiffness, or corrosion resistance than is afforded by the pure metal. Lead compounds are used in glazes and paints. About one third of U.S. lead consumption goes into storage batteries. About half of U.S. lead consumption is from secondary lead recovery. U.S. consumption of lead is in the range of one million tons annually.

Lead ingested by humans produces a variety of toxic effects including impaired reproductive ability, disturbances in blood chemistry, neurological disorders, kidney damage, and adverse cardiovascular effects. Exposure to lead in the diet results in permanent increase in lead levels in the body. Most of the lead entering the body eventually becomes localized in the bones where it accumulates. Lead is a carcinogen or cocarcinogen in some species of experimental animals. Lead is teratogenic in experimental animals. Mutagenicity data are not available for lead.

The ambient water quality criterion for lead is recommended to be identical to the existng drinking water standard which is 0.050 mg/l. Available data show that adverse effects on aquatic life occur at concentrations as low as 7.5×10^{-4} mg/l of total recoverable lead as a 24-hour average with a water hardness of 50 mg/l as $CaCO_3$.

Lead is not destroyed in a POTW, but is passed through to the effluent or retained in the POTW sludge; it can interfere with POTW treatment processes and can limit the usefulness of POTW sludge for application to agricultural croplands. Threshold concentration for inhibition of the activated sludge process is 0.1 mg/l, and for the nitrification process is 0.5 mg/l. In a study of 214 POTW facilities, median pass through values were over 80 percent for primary plants and over 60 percent for trickling filter, activated sludge, and biological process plants. Lead concentration in POTW effluents ranged from 0.003 to 1.8 mg/l (mean = 0.106 mg/l, standard deviation = 0.222).

Application of lead-containing sludge to cropland should not lead to uptake by crops under most conditions because normally lead is strongly bound by soil. However, under the unusual condition of low pH (less than 5.5) and low concentrations of labile phosphorus, lead solubility is increased and plants can accumulate lead.

Mercury (123). Mercury is an elemental metal rarely found in nature as the free metal. Mercury is unique among metals as it remains a liquid down to about 39 degrees below zero. It is relatively inert chemically and is insoluble in water. The principal ore is cinnabar (HgS).

Mercury is used industrially as the metal and as mercurous and mercuric salts and compounds. Mercury is used in several types of batteries. Mercury released to the aqueous environment is subject to biomethylation - conversion to the extremely toxic methyl mercury.

Mercury can be introduced into the body through the skin and the respiratory system as the elemental vapor. Mercuric salts are highly toxic to humans and can be absorbed through the gastrointestinal tract. Fatal doses can vary from 1 to 30 grams. Chronic toxicity of methyl mercury is evidenced primarily by neurological symptoms. Some mercuric salts cause death by kidney failure.

Mercuric salts are extremely toxic to fish and other aquatic life. Mercuric chloride is more lethal than copper, hexavalent chromium, zinc, nickel, and lead towards fish and aquatic life. In the food cycle, algae containing mercury up to 100 times the concentration in the surrounding sea water are eaten by fish which further concentrate the mercury. Predators that eat the fish in turn concentrate the mercury even further.

For the protection of human health from the toxic properties of mercury ingested through water and through contaminated aquatic organisms the ambient water criterion is determined to be 0.0002 mg/l.

Mercury is not destroyed when treated by a POTW, and will either pass through to the POTW effluent or be incorporated into the POTW sludge. At low concentrations it may reduce POTW removal efficiencies, and at high concentrations it may upset the POTW operation.

The influent concentrations of mercury to a POTW have been observed by the EPA to range from 0.002 to 0.24 mg/l, with a median concentration of 0.001 mg/l. Mercury has been reported in the literature to have inhibiting effects upon an activated sludge POTW at levels as low as 0.1 mg/l. At 5 mg/l of mercury, losses of COD removal efficiency of 14 to 40 percent have been reported, while at 10 mg/l loss of removal of 59 percent has been reported. Upset of an activated sludge POTW is reported in the literature to occur near 200 mg/l. The anaerobic digestion process is much less affected by the presence of mercury, with inhibitory effects being reported at 1,365 mg/l.

In a study of 22 POTW facilities having secondary treatment, the range of removal of mercury from the influent to the POTW ranged from 4 to 99 percent with median removal of 41 percent. Thus significant pass through of mercury may occur.

In sludges, mercury content may be high if industrial sources of mercury contamination are present. Little is known about the form in which mercury occurs in sludge. Mercury may undergo biological methylation in sediments, but no methylation has been observed in soils, mud, or sewage sludge.

The mercury content of soils not receiving additions of POTW sewage sludge lie in the range from 0.01 to 0.5 mg/kg. In soils receiving POTW sludges for protracted periods, the concentration of mercury has been observed to approach 1.0 mg/kg. In the soil, mercury enters into reactions with the exchange complex of clay and organic fractions, forming both ionic and covalent bonds. Chemical and microbiological degradation of mercurials can take place side by side in the soil, and the products - ionic or molecular - are retained by organic matter and clay or may be volatilized if gaseous. Because of the high affinity between mercury and the solid soil surfaces, mercury persists in the upper layer of the soil.

Mercury can enter plants through the roots, it can readily move to other parts of the plant, and it has been reported to cause injury to plants. In many plants mercury concentrations range from 0.01 to 0.20 mg/kg, but when plants are supplied with high levels of mercury, these concentrations can exceed 0.5 mg/kg. Bioconcentration occurs in animals ingesting mercury in food.

Nickel (124). Nickel is seldom found in nature as the pure elemental metal. It is a relatively plentiful element and is widely distributed throughout the earth's crust. It occurs in marine organisms and is found in the oceans. The chief commercial ores for nickel are pentlandite [$(Fe,Ni)_9S_8$], and a lateritic ore consisting of hydrated nickel-iron-magnesium silicate.

Nickel has many and varied uses. It is used in alloys and as the pure metal. Nickel salts are used for electroplating baths.

The toxicity of nickel to man is thought to be very low, and systemic poisoning of human beings by nickel or nickel salts is almost unknown. In non-human mammals nickel acts to inhibit insulin release, depress growth, and reduce cholesterol. A high incidence of cancer of the lung and nose has been reported in humans engaged in the refining of nickel.

Nickel salts can kill fish at very low concentrations. However, nickel has been found to be less toxic to some fish than copper, zinc, and iron. Nickel is present in coastal and open ocean water at concentrations in the range of 0.0001 to 0.006 mg/l although the most common values are 0.002 to 0.003 mg/l. Marine animals contain up to 0.4 mg/l and marine plants contain up to 3 mg/l. Higher nickel concentrations have been reported to cause reduction in photosynthetic activity of the giant kelp. A low concentration was found to kill oyster eggs.

For the protection of human health based on the toxic properties of nickel ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 0.0134 mg/l. If contaminated aquatic organisms are consumed, excluding consumption of water, the ambient water criterion is determined to be 0.100 mg/l. Available data show that adverse effects on aquatic life occur for total recoverable nickel concentrations as low as 0.0071 mg/l as a 24-hour average.

Nickel is not destroyed when treated in a POTW, but will either pass through to the POTW effluent or be retained in the POTW sludge. It can interfere with POTW treatment processes and can also limit the usefulness of municipal sludge.

Nickel salts have caused inhibition of the biochemical oxidation of sewage in a POTW. In a pilot plant, slug doses of nickel significantly reduced normal treatment efficiencies for a few hours, but the plant acclimated itself somewhat to the slug dosage and appeared to achieve normal treatment efficiencies within 40 hours. It has been reported that the anaerobic digestion process is inhibited only by high concentrations of nickel, while a low concentration of nickel inhibits the nitrification process.

The influent concentration of nickel to a POTW has been observed by the EPA to range from 0.01 to 3.19 mg/l, with a median of 0.33 mg/l. In a study of 190 POTW facilities, nickel pass-through was greater than 90 percent for 82 percent of the primary plants. Median pass-through for trickling filter, activated sludge, and biological process plants was greater than 80 percent. POTW effluent concentrations ranged from 0.002 to 40 mg/l (mean = 0.410, standard deviation = 3.279).

Nickel not passed through the POTW will be incorporated into the sludge. In a recent two-year study of eight cities, four of the cities had median nickel concentrations of over 350 mg/kg, and two were over 1,000 mg/kg. The maximum nickel concentration observed was 4,010 mg/kg.

Nickel is found in nearly all soils, plants, and waters. Nickel has no known essential function in plants. In soils, nickel typically is found in the range from 10 to 100 mg/kg. Various environemntal exposures to nickel appear to correlate with increased incidence of tumors in man. For example, cancer in the maxillary antrum of snuff users may result from using plant materials grown on soil high in nickel.

Nickel toxicity may develop in plants from application of sewage sludge on acid soils. Nickel has caused reduction of yields for a variety of crops including oats, mustard, turnips, and cabbage. In one study nickel decreased the yields of oats significantly at 100 mg/kg.

Whether nickel exerts a toxic effect on plants depends on several soil factors, the amount of nickel applied, and the contents of other metals in the sludge. Unlike copper and zinc, which are more available from inorganic sources than from sludge, nickel uptake by plants seems to be promoted by the presence of the organic matter in sludge. Soil treatments, such as liming, reduce the solubility of nickel. Toxicity of nickel to plants is enhanced in acidic soils.

Selenium (125). Selenium (chemical symbol Se) is a non-metallic element existing in several allotropic forms. Gray selenium, which has a metallic appearance, is the stable form at ordinary temperatures and melts at 220°C. Selenium is a major component of 38 minerals and a minor component of 37 others found in various parts of the world. Most selenium is obtained as a by-product of precious metals recovery from electrolytic copper refinery slimes. U.S. annual production at one time reached one million pounds.

Principal uses of selenium are in semi-conductors, pigments, decoloring of glass, zerography, and metallurgy. It also is used to produce ruby glass used in signal lights. Several selenium compounds are important oxidizing agents in the synthesis of organic chemicals and drug products.

While results of some studies suggest that selenium may be an essential element in human nutrition, the toxic effects of selenium in humans are well established. Lassitude, loss of hair, discoloration and loss of fingernails are symptoms of selenium poisoning. In a fatal case of ingestion of a larger dose of selenium acid, peripheral vascular collapse, pulmonary edema, and coma occurred. Selenium produces mutagenic and teratogenic effects, but it has not been established as exhibiting carcinogenic activity.

For the protection of human health from the toxic properties of selenium ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 0.010 mg/l, i.e., the same as the drinking water standard. Available data show that adverse effects on aquatic life occur at concentrations higher than that cited for human toxicity.

Very few data are available regarding the behavior of selenium in a POTW. One EPA survey of 103 POTW facilities revealed one POTW using biological treatment and having selenium in the influent. Influent concentration was 0.0025 mg/l, effluent concentration was 0.0016 mg/l, giving a removal of 37 percent. It is not known to be inhibitory to POTW processes. In another study, sludge from POTW facilities in 16 cities was found to contain from 1.8 to 8.7 mg/kg selenium, compared to 0.01 to 2 mg/kg in untreated soil. These concentrations of selenium in sludge present a potential hazard for humans or other mammals eating crops grown on soil treated with selenium-containing sludge.

Silver (126). Silver is a soft, lustrous, white metal that is insoluble in water and alkali. In nature, silver is found in the elemental state (native silver) and combined in ores such as argentite (Ag_2S), horn silver ($AgCl$), proustite (Ag_3AsS_3), and pyrargyrite (Ag_3SbS_3). Silver is used extensively in several industries, among them electroplating.

Metallic silver is not considered to be toxic, but most of its salts are toxic to a large number of organisms. Upon ingestion by humans, many silver salts are absorbed in the circulatory system and deposited in various body tissues, resulting in generalized or sometimes localized gray pigmentation of the skin and mucous membranes known as argyria. There is no known method for removing silver from the tissues once it is deposited, and the effect is cumulative.

Silver is recognized as a bactericide and doses from 0.000001 to 0.0005 mg/l have been reported as sufficient to sterilize water. The criterion for ambient water to protect human health from the toxic properties of silver ingested through water and through contaminated aquatic organisms is 0.010 mg/l.

The chronic toxic effects of silver on the aquatic environment have not been given as much attention as many other heavy metals. Data from existing literature support the fact that silver is very toxic to aquatic organisms. Despite the fact that silver is nearly the most toxic of the heavy metals, there are insufficient data to adequately evaluate even the effects of hardness on silver toxicity. There are no data available on the toxicity of different forms of silver.

There is no available literature on the incidental removal of silver by a POTW. An incidental removal of about 50 percent is assumed as being representative. This is the highest average incidental removal of any metal for which data are available. (Copper has been indicated to have a median incidental removal rate of 49 percent.)

Bioaccumulation and concentration of silver from sewage sludge has not been studied to any great degree. There is some indication that silver could be bioaccumulated in mushrooms to the extent that there could be adverse physiological effects on humans if they consumed large quantities of mushrooms grown in silver enriched soil. The effect, however, would tend to be unpleasant rather than fatal.

There is little summary data available on the quantity of silver discharged to a POTW. Presumably there would be a tendency to limit its discharge from a manufacturing facility because of its high intrinsic value.

Thallium (127). Thallium (Tl) is a soft, silver-white, dense, malleable metal. Five major minerals contain 15 to 85 percent thallium, but they are not of commercial importance because the metal is produced in sufficient quantity as a by-product of lead-zinc smelting of sulfide ores. Thallium melts at 304°C. U.S. annual production of thallium and its compounds is estimated to be 1,500 pounds.

Industrial uses of thallium include the manufacture of alloys, electronic devices and special glass. Thallium catalysts are used for industrial organic syntheses.

Acute thallium poisoning in humans has been widely described. Gastrointestinal pains and diarrhea are followed by abnormal sensation in the legs and arms, dizziness, and, later, loss of hair. The central nervous system is also affected. Somnolence, delerium or coma may occur. Studies on the teratogenicity of thallium appear inconclusive; no studies on mutagenicity were found; and no published reports on carcinogenicity of thallium were found.

For the protection of human health from the toxic properties of thallium ingested through water and contaminated aquatic organisms, the ambient water criterion is 0.004 mg/l.

No reports were found regarding the behavior of thallium in a POTW. It will not be degraded, therefore it must pass through to the effluent or be removed with the sludge. However, since the sulfide (TlS) is very insoluble, if appreciable sulfide is present dissolved thallium in the influent to a POTW may be precipitated into the sludge. Subsequent use of sludge bearing thallium compounds as a soil amendment to crop bearing soils may result in uptake of this element by food plants. Several leafy garden crops (cabbage, lettuce, leek, and endive) exhibit relatively higher concentrations of thallium than other foods such as meat.

Zinc (128). Zinc occurs abundantly in the earth's crust, concentrated in ores. It is readily refined into the pure, stable, silver-white metal. In addition to its use in alloys, zinc is used as a protective coating on steel. It is applied by hot dipping (i.e., dipping the steel in molten zinc) or by electroplating.

Zinc can have an adverse effect on man and animals at high concentrations. Zinc at concentrations in excess of 5 mg/l causes an undesirable taste which persists through conventional treatment. For the prevention of adverse effects due to these organoleptic properties of zinc, 5 mg/l was adopted for the ambient water criterion. Available data show that adverse effects on aquatic life occur at concentrations as low as 0.047 mg/l as a 24-hour average.

Toxic concentrations of zinc compounds cause adverse changes in the morphology and physiology of fish. Lethal concentrations in the range of 0.1 mg/l have been reported. Acutely toxic concentrations induce cellular breakdown of the gills, and possibly the clogging of the gills with mucous. Chronically toxic concentrations of zinc compounds cause general enfeeblement and widespread histological changes to many organs, but not to gills. Abnormal swimming behavior has been reported at 0.04 mg/l. Growth and maturation are retarded by zinc. It has been observed that the effects of zinc poisoning may not become apparent immediately, so that fish removed from zinc-contaminated water may die as long as 48 hours after removal.

In general, salmonoids are most sensitive to elemental zinc in soft water; the rainbow trout is the most sensitive in hard waters. A complex relationship exists between zinc concentration, dissolved zinc concentration, pH, temperature, and calcium and magnesium concentration. Prediction of harmful effects has been less than reliable and controlled studies have not been extensively documented.

The major concern with zinc compounds in marine waters is not with acute lethal effects, but rather with the long-term sublethal effects of the metallic compounds and complexes. Zinc accumulates in some marine species, and marine animals contain zinc in the range of 6 to 1,500 mg/kg. From the point of view of acute lethal effects, invertebrate marine animals seem to be the most sensitive organism tested.

Toxicities of zinc in nutrient solutions have been demonstrated for a number of plants. A variety of fresh water plants tested manifested harmful symptoms at concentrations of 0.030 to 21.6 mg/l. Zinc sulfate has also been found to be lethal to many plants and it could impair agricultural uses of the water.

Zinc is not destroyed when treated by a POTW, but will either pass through to the POTW effluent or be retained in the POTW sludge. It can interfere with treatment processes in the POTW and can also limit the usefulness of municipal sludge.

In slug doses, and particularly in the presence of copper, dissolved zinc can interfere with or seriously disrupt the operation of POTW biological processes by reducing overall removal efficiencies, largely as a result of the toxicity of the metal to biological organisms. However, zinc solids in the form of hydroxides or sulfides do not appear to interfere with biological treatment processes, on the basis of available data. Such solids accumulate in the sludge.

The influent concentrations of zinc to a POTW has been observed by the EPA to range from 0.017 to 3.91 mg/l, with a median concentration of 0.33 mg/l. Primary treatment is not efficient in removing zinc; however, the microbial floc of secondary treatment readily adsorbs zinc.

In a study of 258 POTW facilities, the median pass-through values were 70 to 88 percent for primary plants, 50 to 60 percent for trickling filter and biological process plants, and 30 to 40 percent for activated process plants. POTW effluent concentrations of zinc ranged from 0.003 to 3.6 mg/l (mean = 0.330, standard deviation = 0.464).

The zinc which does not pass through the POTW is retained in the sludge. The presence of zinc in sludge may limit its use on cropland. Sewage sludge contains 72 to over 30,000 mg/kg of zinc, with 3,366 mg/kg as the mean value. These concentrations are significantly greater than those normally found in soil, which range from 0 to 195 mg/kg, with 94 mg/kg being a common level. Therefore, application of sewage sludge to soil will generally increase the concentration of zinc in the soil. Zinc can be toxic to plants, depending upon soil pH. Lettuce, tomatoes, turnips, mustard, kale, and beets are especially sensitive to zinc contamination.

Oil and Grease. Oil and grease are taken together as one pollutant parameter. This is a conventional pollutant and some of its components are:

1. Light Hydrocarbons - These include light fuels such as gasoline, kerosene, and jet fuel, and miscellaneous solvents used for industrial processing, degreasing, or cleaning purposes. The presence of these light hydrocarbons may make the removal of other heavier oil wastes more difficult.

2. Heavy Hydrocarbons, Fuels, and Tars - These include the crude oils, diesel oils, #6 fuel oil, residual oils, slop oils, and in some cases, asphalt and road tar.

3. Lubricants and Cutting Fluids - These generally fall into two classes: non-emulsifiable oils such as lubricating oils and greases and emulsifiable oils such as water soluble oils, rolling oils, cutting oils, and drawing compounds. Emulsifiable oils may contain fat, soap, or various other additives.

4. Vegetable and Animal Fats and Oils - These originate primarily from processing of foods and natural products.

These compounds can settle or float and may exist as solids or liquids depending upon factors such as method of use, production process, and temperature of water.

Oil and grease even in small quantities cause troublesome taste and odor problems. Scum lines from these agents are produced on water treatment basin walls and other containers. Fish and water fowl are adversely affected by oils in their habitat. Oil emulsions may adhere to the gills of fish causing suffocation, and the flesh of fish is tainted when microorganisms that were exposed to waste oil are eaten. Deposition of oil in the bottom sediments of water can serve to inhibit normal benthic growth. Oil and grease exhibit an oxygen demand.

Many of the toxic organic pollutants will be found distributed between the oil phase and the aqueous phase in industrial wastewaters. The presence of phenols, PCB's, PAH's, and almost any other organic pollutant in the oil and grease make characterization of this parameter almost impossible. However, all of these other organics add to the objectionable nature of the oil and grease.

Levels of oil and grease which are toxic to aquatic organisms vary greatly, depending on the type and the species susceptibility. However, it has been reported that crude oil in concentrations as low as 0.3 mg/l is extremely toxic to freshwater fish. It has been recommended that public water supply sources be essentially free from oil and grease.

Oil and grease in quantities of 100 l/sq km show up as a sheen on the surface of a body of water. The presence of oil slicks decreases the aesthetic value of a waterway.

Oil and grease is compatible with a POTW activated sludge process in limited quantity. However, slug loadings or high concentrations of oil and grease interfere with biological treatment processes. The oils coat surfaces and solid particles, preventing access of oxygen, and sealing in some microorganisms. Land spreading of POTW sludge containing oil and grease uncontaminated by toxic pollutants is not expected to affect crops grown on the treated land, or animals eating those crops.

pH. Although not a specific pollutant, pH is related to the acidity or alkalinity of a wastewater stream. It is not, however, a measure of either. The term pH is used to describe the hydrogen ion concentration (or activity) present in a given solution. Values for pH range from 0 to 14, and these numbers are the negative logarithms of the hydrogen ion concentrations. A pH of 7 indicates neutrality. Solutions with a pH above 7 are alkaline, while those solutions with a pH below 7 are acidic. The relationship of pH and acidity and alkalinity is not necessarily linear or direct. Knowledge of the water pH is useful in determining necessary measures for corrosion control, sanitation, and disinfection. Its value is also necessary in the treatment of industrial wastewaters to determine amounts of chemicals required to remove pollutants and to measure their effectiveness. Removal of pollutants, especially dissolved solids is affected by the pH of the wastewater.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add constituents to drinking water such as iron, copper, zinc, cadmium, and lead. The hydrogen ion concentration can affect the taste of the water, and at a low pH water tastes sour. The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7.0. This is significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Even moderate changes from acceptable criteria limits of pH are deleterious to some species.

The relative toxicity to aquatic life of many materials is increased by changes in the water pH. For example, metallocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units.

Because of the universal nature of pH and its effect on water quality and treatment, it is selected as a pollutant parameter for many industry categories. A neutral pH range (approximately 6 to 9) is generally desired because either extreme beyond this range has a deleterious effect on receiving waters or the pollutant nature of other wastewater constituents.

Pretreatment for regulation of pH is covered by the "General Pretreatment Regulations for Existing and New Sources of Pollution," 40 CFR 403.5. This section prohibits the discharge to a POTW of "pollutants which will cause corrosive structural damage to the POTW but in no case discharges with pH lower than 5.0 unless the works is specially designed to accommodate such discharges."

Total Suspended Solids (TSS). Suspended solids include both organic and inorganic materials. The inorganic compounds include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, and animal and vegetable waste products. These solids may settle out rapidly, and bottom deposits are often a mixture of both organic and inorganic solids. Solids may be suspended in water for a time and then settle to the bed of the stream or lake. These solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, suspended solids increase the turbidity of the water, reduce light penetration, and impair the photosynthetic activity of aquatic plants.

Suspended solids in water interfere with many industrial processes and cause foaming in boilers and incrustations on equipment exposed to such water, especially as the temperature rises. They are undesirable in process water used in the manufacture of steel, in the textile industry, in laundries, in dyeing, and in cooling systems.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often damaging to the life in the water. Solids, when transformed to sludge deposit, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a food source for sludgeworms and associated organisms.

Disregarding any toxic effect attributable to substances leached out by water, suspended solids may kill fish and shellfish by causing abrasive injuries and by clogging the gills and respiratory passages of various aquatic fauna. Indirectly, suspended solids are inimical to aquatic life because they screen out light, and they promote and maintain the development of noxious conditions through oxygen depletion. This results in the killing of fish and fish food organisms. Suspended solids also reduce the recreational value of the water.

Total suspended solids is a traditional pollutant which is compatible with a well-run POTW. This pollutant with the exception of those components which are described elsewhere in this section, e.g., heavy metal components, does not interfere with the operation of a POTW. However, since a considerable portion of the innocuous TSS may be inseparably bound to the constituents which do interfere with POTW operation, or produce unusable sludge, or subsequently dissolve to produce unacceptable POTW effluent, TSS may be considered a toxic waste.

Aluminum. Aluminum, a nonconventional pollutant, is the most common metallic element in the earth's crust, and the third most abundant element (8.1 percent). It is never found free in nature. Most rocks and various clays contain aluminum in the form of aluminosilicate minerals. Generally, aluminum is first converted to alumina (Al_2O_3) from bauxite ore. The alumina then undergoes electrolytic reduction to form the metal. Aluminum powders (used in explosives, fireworks, and rocket fuels) form flammable mixtures in the air. Aluminum metal resists corrosion under many conditions by forming a protective oxide film on the surface. This oxide layer corrodes rapidly in strong acids and alkalis, and by the electrolytic action of other metals with which it comes in contact. Aluminum is light, malleable, ductile, possesses high thermal and electrical conductivity, and is non-magnetic. It can be formed, machined, or cast. Aluminum is used in the building and construction, transportation, and the container and packaging industries and competes with iron and steel in these markets. Total U.S. production of primary aluminum in 1981 was 4,948,000 tons. Secondary aluminum (from old scrap) production in 1981 was 886,000 tons. Production of primary aluminum is currently declining.

Aluminum is soluble under both acidic and basic conditions, with environmental transport occurring most readily under these conditions. In water, aluminum can behave as an acid or base, can form ionic complexes with other substances, and can polymerize, depending on pH and the dissolved substances in water. Aluminum's high solubility at acidic pH conditions makes it readily available for accumulation in aquatic life. Acidic waters consistently contain higher levels of soluble aluminum than neutral or alkaline waters. Loss of aquatic life in acidified lakes and streams has been shown to be due in part to increased concentrations of aluminum in waters as a result of leaching of aluminum from soil by acidic rainfall.

Aluminum has been found to be toxic to freshwater and marine aquatic life. In freshwaters acute toxicity and solubility increases as pH levels increase above pH 7. This relationship also appears to be true as the pH levels decrease below pH 7. Chronic effects of aluminum on aquatic life have also been documented. Aluminum has been found to be toxic to certain plants. A water quality standard for aluminum was estabished (U.S. Federal Water Pollution Control Administration, 1968) for interstate agricultural and irrigation waters, which set a trace element tolerance at 1 mg/l for continuous use on all soils and 20 mg/l for short term use on fine-textured soils.

There are no reported adverse physiological effects on man from exposure to low concentrations of aluminum in drinking water. Large concentrations of aluminum in the human body, however, are alleged to cause changes in behavior. Aluminum compounds, especially aluminum sulfate, are major coagulants used in the treatment of drinking water. Aluminum is not among the metals for which a drinking water standard has been established.

The highest aluminum concentrations in animals and humans occur in the lungs, mostly from the inhalation of airborne particulate matter. Pulmonary fibrosis has been associated with the inhalation of very fine particles of aluminum flakes and powders among workers in the explosives and fireworks industries. An occupational exposure Threshold Limit Value (TLV) of 5 mg/m^3 is recommended for pyro powders to prevent lung changes, and a Time-Weighted Average (TWA) of 10 mg/m^3 is recommended for aluminum dust. High levels of aluminum have been found in the brains, muscles, and bones of patients with chronic renal failure who are being treated with aluminum hydroxide, and high brain levels of aluminum are found in those suffering from Alzheimers disease (presenile dementia) which manifests behavioral changes.

Aluminum and some of its compounds used in food preparation and as food additives are generally recognized as safe and are sanctioned by the Food and Drug Administration. No limits on aluminum content in food and beverage products have been established.

Aluminum has no adverse effects on POTW operation at concentrations normally encountered. The results of an EPA study of 50 POTWs revealed that 49 POTWs contained aluminum with effluent concentrations ranging from less than 0.1 mg/l to 1.07 mg/l and with an average removal of 82 percent.

Ammonia. Ammonia (chemical formula NH_3) is a nonconventional pollutant. It is a colorless gas with a very pungent odor, detectable at concentrations of 20 ppm in air by the nose, and is very soluble in water (570 gm/l at 25°C). Ammonia is produced industrially in very large quantities (nearly 20 million tons annually in the U.S.). It is converted to ammonium compounds or shipped in the liquid form (it liquifies at -33°C). Ammonia also results from natural processes. Bacterial action on nitrates or nitrites, as well as dead plant and animal tissue and animal wastes produces ammonia. Typical domestic wastewaters contain 12 to 50 mg/l ammonia.

The principal use of ammonia and its compounds is as fertilizer. High amounts are introduced into soils and the water runoff from agricultural land by this use. Smaller quantities of ammonia are used as a refrigerant. Aqueous ammonia (2 to 5 percent solution) is widely used as a household cleaner. Ammonium compounds find a variety of uses in various industries, as an example, ammonium hydroxide is used as a reactant in the purification of tungsten.

Ammonia is toxic to humans by inhalation of the gas or ingestion of aqueous solutions. The ionized form, ammonium (NH_4+), is less toxic than the unionized form. Ingestion of as little as one ounce of household ammonia has been reported as a fatal dose. Whether inhaled or ingested, ammonia acts distructively on mucous membrane with resulting loss of function. Aside from breaks in liquid ammonia refrigeration equipment, industrial hazard from ammonia exists where solutions of ammonium compounds may be accidently treated with a strong alkali, releasing ammonia gas. As little as 150 ppm ammonia in air is reported to cause laryngeal spasms, and inhalation of 5,000 ppm in air is considered sufficient to result in death.

The behavior of ammonia in POTW is well documented because it is a natural component of domestic wastewaters. Only very high concentrations of ammonia compounds could overload POTW. One study has shown that concentrations of unionized ammonia greater than 90 mg/l reduce gasification in anaerobic digesters and concentrations of 140 mg/l stop digestion completely. Corrosion of copper piping and excessive consumption of chlorine also result from high ammonia concentrations. Interference with aerobic nitrification processes can occur when large concentrations of ammonia suppress dissolved oxygen. Nitrites are then produced instead of nitrates. Elevated nitrite concentrations in drinking water are known to cause infant methemoglobinemia.

Fluoride. Fluoride ion (F-) is a nonconventional pollutant. Fluorine is an extremely reactive, pale yellow, gas which is never found free in nature. Compounds of fluorine - fluorides - are found widely distributed in nature. The principal minerals containing fluorine are fluorspar (CaF_2) and cryolite (Na_2AlF_6). Although fluorine is produced commercially in small quantities by electrolysis of potassium bifluoride in anhydrous hydrogen fluoride, the elemental form bears little relation to the combined ion. Total production of fluoride chemicals in the U.S. is difficult to estimate because of the varied uses. Large volume usage compounds are: calcium fluoride (estimated 1,500,000 tons in U.S.) and sodium fluoraluminate (estimated 100,000 tons in U.S.). Some fluoride compounds and their uses are sodium fluoroaluminate - aluminum production; calcium fluoride - steelmaking, hydrofluoric acid production, enamel, iron foundry; boron trifluoride - organic synthesis; antimony pentafluoride - fluorocarbon production; fluoboric acid and fluoborates - electroplating; perchloryl fluoride (ClO_3F) - rocket fuel oxidizer; hydrogen fluoride - organic fluoride manufacture, pickling acid in stainless steelmaking, manufacture of aluminum fluoride; sulfur hexafluoride - insulator in high voltage transformers; polytetrafluoroethylene - inert plastic. Sodium fluoride is used at a concentration of about 1 pm in many public drinking water supplies to prevent tooth decay in children.

The toxic effects of fluoride on humans include severe gastroenteritis, vomiting, diarrhea, spasms, weakness, thirst, failing pulse and delayed blood coagulation. Most observations of toxic effects are made on individuals who intentionally or accidentally ingest sodium fluoride intended for use as rat poison or insecticide. Lethal doses for adults are estimated to be as low as 2.5 g. At 1.5 ppm in drinking water, mottling of tooth enamel is reported, and 14 ppm, consumed over a period of years, may lead to deposition of calcium fluoride in bone and tendons.

Fluorides found in irrigation waters in high concentrations have caused damage to certain plants exposed to these waters. Chronic fluoride poisoning of livestock has been observed. Fluoride from waters apparently does not accumulate in soft tissue to a significant degree; it is transferred to a very small extent into the milk and to a somewhat greater degree in eggs. Data for fresh water indicate that fluorides are toxic to fish.

Very few data are available on the behavior of fluoride in POTW. Under usual operating conditions in POTW, fluorides pass through into the effluent. Very little of the fluoride entering conventional primary and secondary treatment processes is removed. In one study of POTW influents conducted by the U.S. EPA, nine POTW reported concentrations of fluoride ranging from 0.7 mg/1 to 1.2 mg/1, which is the range of concentrations used for fluoridated drinking water.

Phenols (Total). "Total Phenols" is a nonconventional pollutant parameter. Total phenols is the result of analysis using the 4-AAP (4-aminoantipyrene) method. This analytical procedure measures the color development of reaction products between 4-AAP and some phenols. The results are reported as phenol. Thus "total phenol" is not total phenols because many phenols (notably nitrophenols) do not react. Also, since each reacting phenol contributes to the color development to a different degree, and each phenol has a molecular weight different from others and from phenol itself, analyses of several mixtures containing the same total concentration in mg/l of several phenols will give different numbers depending on the proportions in the particular mixture.

Despite these limitations of the analytical method, total phenols is a useful parameter when the mix of phenols is relatively constant and an inexpensive monitoring method is desired. In any given plant or even in an industry subcategory, monitoring of "total phenols" provides an indication of the concentration of this group of priority pollutants as well as those phenols not selected as priority pollutants. A further advantage is that the method is widely used in water quality determinations.

In an EPA survey of 103 POTW the concentration of "total phenols" ranged from 0.0001 mg/l to 0.176 mg/l in the influent, with a median concentration of 0.016 mg/l. Analysis of effluents from 22 of these same POTW which had biological treatment meeting secondary treatment performance levels showed "total phenols" concentrations ranging from 0 mg/l to 0.203 mg/l with a median of 0.007. Removals were 64 to 100 percent with a median of 78 percent.

It must be recognized, however, that six of the eleven priority pollutant phenols could be present in high concentrations and not be detected. Conversely, it is possible, but not probable, to have a high "total phenol" concentration without any phenol itself or any of the 10 other priority pollutant phenols present. A characterization of the phenol mixture to be monitored to establish constancy of composition will allow "total phenols" to be used with confidence.

SUMMARY OF POLLUTANT SELECTION

After examining the sampling data, pollutants and pollutant parameters were selected by subcategory for further consideration for limitation. The selection of a pollutant was based on the concentration of the pollutant in the raw sampling data and the frequency of occurrence above concentrations considered treatable. Paragraph 8(a)(iii) allows the exclusion of a toxic pollutant if it is not detected, if it is present in amounts too small to be effectively reduced by technologies known to the

Administrator, if it is detected in the effluent from only a small number of sources, or if it is present solely as a result of its presence in the intake waters. The exclusion and selection of pollutants that took place under this rationale are listed below. The analysis that led to the selection of these toxic pollutants is presented in Section VI of each subcategory supplement.

Pollutants Selected for Further Consideration by Subcategory

Primary Aluminum Smelting Subcategory

1. acenaphthene
39. fluoranthene
72. benzo(a)anthracene (1,2-benzanthracene)
73. benzo(a)pyrene
76. chrysene
77. acenaphthylene
78. anthracene (a)
79. benzo(ghi)perylene (1,11-benzoperylene)
80. fluorene
81. phenanthrene (a)
82. dibenzo(a,h)anthracene (1,2,5,6-dibenzanthracene)
84. pyrene
114. antimony
115. arsenic
116. asbestos
118. cadmium
119. chromium (Total)
120. copper
121. cyanide (Total)
122. lead
124. nickel
125. selenium
128. zinc

aluminum
fluoride
oil and grease
TSS
pH

(a) Reported together

Secondary Aluminum Subcategory

118. cadmium
122. lead
128. zinc
aluminum
ammonia (N)
oil and grease
TSS
pH

Primary Electrolytic Copper Refining Subcategory

115. arsenic
119. chromium (Total)
120. copper
122. lead
124. nickel
126. silver
128. zinc
TSS
pH

Primary Lead Subcategory

116. asbestos
118. cadmium
122. lead
128. zinc
TSS
pH

Primary Zinc Subcategory

115. arsenic
116. asbestos
118. cadmium
119. chromium (Total)
120. copper
122. lead
124. nickel
126. silver
128. zinc
TSS
pH

Metallurgical Acid Plants Subcategory

114. antimony
115. arsenic
118. cadmium
119. chromium (Total)
120. copper
122. lead
123. mercury
124. nickel
125. selenium
126. silver
128. zinc
TSS
pH

Primary Tungsten Subcategory

1. acenaphthene
55. naphthalene
77. acenaphthylene
80. fluorene
118. cadmium
119. chromium (Total)
122. lead
125. selenium
127. thallium
128. zinc
ammonia (N)
TSS
pH

Primary Columbium-Tantalum Subcategory

7. chlorobenzene
8. 1,2,4-trichlorobenzene
10. 1,2-dichloroethane
38. ethylbenzene
51. chlorodibromomethane
87. trichloroethylene
114. antimony
115. arsenic
116. asbestos
118. cadmium
119. chromium (Total)
120. copper

122. lead
124. nickel
125. selenium
127. thallium
128. zinc
ammonia (N)
fluoride
TSS
pH

Secondary Silver Subcategory

4. benzene
6. carbon tetrachloride (tetrachloromethane)
10. 1,2-dichloroethane
29. 1,1-dichloroethylene
87. trichloroethylene
114. antimony
115. arsenic
118. cadmium
119. chromium (Total)
120. copper
121. cyanide
122. lead
124. nickel
125. selenium
126. silver
127. thallium
128. zinc
ammonia (N)
TSS
pH

Secondary Lead Subcategory

114. antimony
115. arsenic
118. cadmium
119. chromium (Total)
120. copper
122. lead
124. nickel
126. silver
127. thallium
128. zinc
TSS
pH

Toxic Pollutants Not Detected

Primary Aluminum Smelting Subcategory

2. acrolein
3. acrylonitrile
5. benzidine
6. carbon tetrachloride (tetrachloromethane)
7. chlorobenzene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene
10. 1.2-dichloroethane
11. 1,1,1-trichlorethane
12. hexachlorethane
13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
15. 1,1,2,2-tetrachloroethane
16. chloroethane
17. DELETED
18. bis (2-chloroethyl) ether
19. 2-chloroethyl vinyl ether (mixed)
21. 2,4,6-trichlorophenol
22. parachlorometa cresol
24. 2-chlorophenol
25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene
28. 3,3'-dichlorobenzidine
29. 1,1-dichloroethylene
30. 1,2-trans-dichloroethylene
31. 2,4-dichlorophenol
32. 1,2-dichloropropane
33. 1,2-dichloropropylene (1,3-dichloropropene)
34. 2,4-dimethylphenol
35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene
37. 1,2-diphenylhydrazine
38. ethylbenzene
40. 4-chlorophenyl phenyl ether
41. 4-bromophenyl phenyl ether
43. bis(2-choroethoxy) methane
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
47. bromoform (tribromomethane)
48. dichlorobromethane
49. DELETED
50. DELETED
51. chlorodibromomethane
52. hexachlorobutadiene
53. hexachlorocyclopentadiene

56. nitrobenzene
57. 2-nitrophenol
58. 4-nitrophenol
59. 2,4-dinitrophenol
60. 4,6-dinitro-o-cresol
61. N-nitrosodimethylamine
63. N-nitrosodi-n-propylamine
64. pentachlorophenol
71. dimethyl phthalate
85. tetrachloroethylene
88. vinyl chloride (chloroethylene)
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

Secondary Aluminum Subcategory

1. acenaphthene
2. acrolein
3. acrylonitrile
5. benzidene
6. carbon tetrachloride (tetrachloromethane)
7. chlorobenzene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene
10. 1,2-dichloroethane
11. 1,1,1-trichlorethane
12. hexachlorethane
13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
15. 1,1,2,2-tetrachloroethane
16. chloroethane
17. DELETED
18. bis (2-chloroethyl) ether
19. 2-chloroethyl vinyl ether (mixed)
20. 2-chloronaphthalene
21. 2,4,6-trichlorophenol
22. parachlorometa cresol
24. 2-chlorophenol
25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
28. 3,3'-dichlorobenzidine
31. 2,4-dichlorophenol
32. 1,2-dichloropropane
33. 1,2-dichloropropylene (1,3-dichloropropene)
34. 2,4-dimethylphenol
35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene
37. 1,2-diphenylhydrazine
38. ethylbenzene
40. 4-chlorophenyl phenyl ether

41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-choroethoxy) methane
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
47. bromoform (tribromomethane)
49. DELETED
50. DELETED
51. chlorodibromomethane
52. hexachlorobutadiene
53. hexachlorocyclopentadiene
54. isophorone
55. naphthalene
56. nitrobenzene
57. 2-nitrophenol
58. 4-nitrophenol
59. 2,4-dinitrophenol
60. 4,6-dinitro-o-cresol
61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine
64. pentachlorophenol
65. phenol
70. diethyl phthalate
72. benzo (a)anthracene (1,2-benzanthracene)
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthene (11,12-benzofluoranthene)
78. anthracene (a)
79. benzo(ghi)perylene (1,11-benzoperylene)
80. fluorene
81. phenanthrene (a)
82. dibenzo (a,h)anthracene (1,2,5,6-dibenzanthracene)
83. indeno (1,2,3-cd)pyrene
86. toluene
88. vinyl chloride (chloroethylene)
89. aldrin
90. dieldrin
94. 4,4'-DDD(p,p'TDE)
95. a-endosulfan-Alpha
96. b-endosulfan-Beta
97. endosulfan sulfate
105. g-BHC-Delta
116. asbestos (Fibrous)
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

(a) Reported together.

Primary Electrolytic Copper Refining Subcategory

2. acrolein
3. acrylonitrile
5. benzidine
6. carbon tetrachloride (tetrachloromethane)
7. chlorobenzene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene
10. 1.2-dichloroethane
12. hexachlorethane
13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
16. chloroethane
17. DELETED
18. bis (2-chloroethyl) ether
19. 2-chloroethyl vinyl ether (mixed)
20. 2-chloronaphthalene
21. 2,4,6-trichlorophenol
22. parachlorometa cresol
24. 2-chlorophenol
25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene
28. 3,3'-dichlorobenzidine
31. 2,4-dichlorophenol
32. 1,2-dichloropropane
33. 1,2-dichloropropylene (1,3-dichloropropene)
34. 2,4-dimethylphenol
35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene
37. 1,2-diphenylhydrazine
38. ethylbenzene
40. 4-chlorophenyl phenyl ether
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-choroethoxy) methane
44. methylene chloride (dichloromethane)
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
47. bromoform (tribromomethane)
48. dichlorobromomethane
49. DELETED
50. DELETED
51. chlorodibromomethane
52. hexachlorobutadiene
53. hexachlorocyclopentadiene
54. isophorone
56. nitrobenzene
57. 2-nitrophenol

58. 4-nitrophenol
59. 2,4-dinitrophenol
60. 4,6-dinitro-o-cresol
61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine
64. pentachlorophenol
65. phenol
70. diethyl phthalate
72. benzo(a)anthracene (1,2-benzanthracene)
74. 3,4-benzofluoranthene
77. acenaphthylene
79. benzo(ghi)perylene (1,11-benzoperylene)
80. fluorene
82. dibenzo (a,h)anthracene (1,2,5,6-dibenzanthracene)
83. indeno (1,2,3-cd)pyrene
86. toluene
88. vinyl chloride (chloroethylene)
89. aldrin
90. dieldrin
94. 4,4'-DDD(p,p'TDE)
105. g-BHC-Delta
113. toxaphene
116. asbestos (Fibrous)
117. beryllium
118. cadmium
121. cyanide (Total)
123. mercury
127. thallium
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

Primary Lead Subcategory

1. acenaphthene
2. acrolein
3. acrylonitrile
5. benzidene
7. chlorobenzene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene
10. 1.2-dichloroethane
11. 1,1,1-trichlorethane
12. hexachlorethane
13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
15. 1,1,2,2-tetrachloroethane
16. chloroethane
17. DELETED
18. bis (2-chloroethyl) ether

19. 2-chloroethyl vinyl ether (mixed)
20. 2-chloronaphthalene
21. 2,4,6-trichlorophenol
22. parachlorometa cresol
24. 2-chlorophenol
25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene
28. 3,3'-dichlorobenzidine
29. 1,1-dichloroethylene
30. 1,2-trans-dichloroethylene
31. 2,4-dichlorophenol
32. 1,2-dichloropropane
33. 1,2-dichloropropylene (1,3-dichloropropene)
34. 2,4-dimethylphenol
35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene
37. 1,2-diphenylhydrazine
38. ethylbenzene
39. fluoranthene
40. 4-chlorophenyl phenyl ether
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-choroethoxy) methane
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
47. bromoform (tribromomethane)
48. dichlorobromomethane
49. DELETED
50. DELETED
51. chlorodibromomethane
52. hexachlorobutadiene
53. hexachlorocyclopentadiene
54. isophorone
55. naphthalene
56. nitrobenzene
57. 2-nitrophenol
58. 4-nitrophenol
59. 2,4-dinitrophenol
60. 4,6-dinitro-o-cresol
61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine
64. pentachlorophenol
65. phenol
66. bis(2-ethylhexyl) phthalate
67. butyl benzyl phthalate
68. di-n-butyl phthalate
69. di-n-octyl phthalate
70. diethyl phthalate

71. dimethyl phthalate
72. benzo(a)anthracene (1,2-benzanthracene)
73. benzo(a)pyrene (3,4-benzopyrene)
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthane (11,12-benzofluoranthene)
76. chrysene
77. acenaphthylene
78. anthracene (a)
79. benzo(ghi)perylene (1,11-benzoperylene)
80. fluorene
81. phenanthrene (a)
82. dibenzo(a,h)anthracene (1,2,5,6-dibenzanthracene)
83. indeno (1,2,3-cd)pyrene
84. pyrene
85. tetrachloroethylene
86. toluene
87. trichloroethylene
88. vinyl chloride (chloroethylene)
89. aldrin
90. dieldrin
91. chlordane (technical mixture and metabolites)
92. 4,4'-DDT
93. 4,4'-DDE(p,p'DDX)
94. 4,4'-DDD(p,p'TDE)
95. a-endosulfan-Alpha
96. b-endosulfan-Beta
97. endosulfan sulfate
98. endrin
99. endrin aldehyde
100. heptachlor
101. heptachlor epoxide
102. a-BHC-Alpha
103. b-BHC-Beta
104. r-BHC (lindane)-Gamma
105. g-BHC-Delta
106. PCB-1242 (Arochlor 1242) (b)
107. PCB-1254 (Arochlor 1254) (b)
108. PCB-1221 (Arochlor 1221) (b)
109. PCB-1232 (Arochlor 1232) (c)
110. PCB-1248 (Arochlor 1248) (c)
111. PCB-1260 (Arochlor 1260) (c)
112. PCB-1016 (Arochlor 1016) (c)
113. toxaphene
121. cyanide (Total)
127. thallium
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

(a), (b), (c) Reported together.

Primary Zinc Subcategory

1. acenaphthene
2. acrolein
3. acrylonitrile
4. benzene
5. benzidene
6. carbon tetrachloride (tetrachloromethane)
7. chlorobenzene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene
10. 1.2-dichloroethane
11. 1,1,1-trichlorethane
12. hexachlorethane
13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
15. 1,1,2,2-tetrachloroethane
16. chloroethane
17. DELETED
18. bis (2-chloroethyl) ether
19. 2-chloroethyl vinyl ether (mixed)
20. 2-chloronaphthalene
21. 2,4,6-trichlorophenol
22. parachlorometa cresol
23. chloroform (trichloromethane)
24. 2-chlorophenol
25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene
28. 3,3'-dichlorobenzidine
29. 1,1-dichloroethylene
30. 1,2-trans-dichloroethylene
31. 2,4-dichlorophenol
32. 1,2-dichloropropane
33. 1,2-dichloropropylene (1,3-dichloropropene)
34. 2,4-dimethylphenol
35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene
37. 1,2-diphenylhydrazine
38. ethylbenzene
39. fluoranthene
40. 4-chlorophenyl phenyl ether
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-choroethoxy) methane
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
47. bromoform (tribromomethane)
48. dichlorobromomethane
49. DELETED

50. DELETED
51. chlorodibromomethane
52. hexachlorobutadiene
53. hexachlorocyclopentadiene
54. isophorone
55. naphthalene
56. nitrobenzene
57. 2-nitrophenol
58. 4-nitrophenol
59. 2,4-dinitrophenol
60. 4,6-dinitro-o-cresol
61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine
64. pentachlorophenol
65. phenol
66. bis(2-ethylhexyl) phthalate
67. butyl benzyl phthalate
68. di-n-butyl phthalate
69. di-n-octyl phthalate
70. diethyl phthalate
71. dimethyl phthalate
72. benzo(a)anthracene (1,2-benzanthracene)
73. benzo(a)pyrene (3,4-benzopyrene)
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthane (11,12-benzofluoranthene)
76. chrysene
77. acenaphthylene
78. anthracene (a)
79. benzo(ghi)perylene (1,11-benzoperylene)
80. fluorene
81. phenanthrene (a)
82. dibenzo(a,h)anthracene (1,2,5,6-dibenzanthracene)
83. indeno (1,2,3-cd)pyrene
84. pyrene
85. tetrachloroethylene
86. toluene
87. trichloroethylene
88. vinyl chloride (chloroethylene)
89. aldrin
90. dieldrin
91. chlordane (technical mixture and metabolites)
92. 4,4'-DDT
93. 4,4'-DDE(p,p'DDX)
94. 4,4'-DDD(p,p'TDE)
95. a-endosulfan-Alpha
96. b-endosulfan-Beta
97. endosulfan sulfate
98. endrin
99. endrin aldehyde

100. heptachlor
101. heptachlor epoxide
102. a-BHC-Alpha
103. b-BHC-Beta
104. r-BHC (lindane)-Gamma
105. g-BHC-Delta
106. PCB-1242 (Arochlor 1242) (b)
107. PCB-1254 (Arochlor 1254) (b)
108. PCB-1221 (Arochlor 1221) (b)
109. PCB-1232 (Arochlor 1232) (c)
110. PCB-1248 (Arochlor 1248) (c)
111. PCB-1260 (Arochlor 1260) (c)
112. PCB-1016 (Arochlor 1016) (c)
113. toxaphene
114. antimony
117. beryllium
121. cyanide (Total)
127. thallium
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

(a), (b), (c) Reported together.

Metallurgical Acid Plants Subcategory

1. acenaphthene
2. acrolein
3. acrylonitrile
5. benzidene
7. chlorobenzene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene
11. 1,1,1-trichlorethane
12. hexachlorethane
16. chloroethane
17. DELETED
18. bis (2-chloroethyl) ether
19. 2-chloroethyl vinyl ether (mixed)
20. 2-chloronaphthalene
21. 2,4,6-trichlorophenol
22. parachlorometa cresol
24. 2-chlorophenol
25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene
28. 3,3'-dichlorobenzidine
29. 1,1-dichloroethylene
30. 1,2-trans-dichloroethylene
31. 2,4-dichlorophenol
32. 1,2-dichloropropane

33. 1,2-dichloropropylene (1,3-dichloropropene)
34. 2,4-dimethylphenol
35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene
37. 1,2-diphenylhydrazine
38. ethylbenzene
40. 4-chlorophenyl phenyl ether
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-choroethoxy) methane
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
47. bromoform (tribromomethane)
50. DELETED
52. hexachlorobutadiene
53. hexachlorocyclopentadiene
56. nitrobenzene
57. 2-nitrophenol
58. 4-nitrophenol
59. 2,4-dinitrophenol
60. 4,6-dinitro-o-cresol
61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine
72. benzo(a)anthracene (1,2-benzanthracene)
77. acenaphthylene
79. benzo(ghi)perylene (1,11-benzoperylene)
82. dibenzo(a,h)anthracene (1,2,5,6-dibenzanthracene)
83. indeno (1,2,3-cd)pyrene
88. vinyl chloride (chloroethylene)
89. aldrin
95. a-endosulfan-Alpha
97. endosulfan sulfate
102. a-BHC-Alpha
105. g-BHC-Delta
113. toxaphene
116. asbestos
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

Primary Tungsten Subcategory

2. acrolein
3. acrylonitrile
5. benzidene
6. carbon tetrachloride (tetrachloromethane)
7. chlorobenzene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene
11. 1,1,1-trichlorethane
12. hexachlorethane

13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
16. chloroethane
17. DELETED
18. bis (2-chloroethyl) ether
19. 2-chloroethyl vinyl ether (mixed)
20. 2-chloronaphthalene
21. 2,4,6-trichlorophenol
22. parachlorometa cresol
24. 2-chlorophenol
25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene
28. 3,3'-dichlorobenzidine
30. 1,2-trans-dichloroethylene
31. 2,4-dichlorophenol
32. 1,2-dichloropropane
33. 1,2-dichloropropylene (1,3-dichloropropene)
34. 2,4-dimethylphenol
35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene
37. 1,2-diphenylhydrazine
40. 4-chlorophenyl phenyl ether
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-choroethoxy) methane
44. methylene chloride (dichloromethane)
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
48. dichlorobromomethane
49. DELETED
50. DELETED
52. hexachlorobutadiene
53. hexachlorocyclopentadiene
54. isophorone
56. nitrobenzene
57. 2-nitrophenol
58. 4-nitrophenol
59. 2,4-dinitrophenol
60. 4,6-dinitro-o-cresol
61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine
64. pentachlorophenol
65. phenol
67. butyl benzyl phthalate
70. diethyl phthalate
71. dimethyl phthalate
72. benzo(a)anthracene (1,2-benzanthracene)
73. benzo(a)pyrene (3,4-benzopyrene)

74. 3,4-benzofluoranthene
75. benzo(k)fluoranthane (11,12-benzofluoranthene)
79. benzo(ghi)perylene (1,11-benzoperylene)
82. dibenzo (a,h)anthracene (1,2,5,6-dibenzanthracene)
83. indeno (1,2,3-cd)pyrene
88. vinyl chloride (chloroethylene)
89. aldrin
90. dieldrin
91. chlordane (technical mixture and metabolites)
92. 4,4'-DDT
93. 4,4'-DDE(p,p'DDX)
94. 4,4'-DDD(p,p'TDE)
96. b-endosulfan-Beta
97. endosulfan sulfate
98. endrin
99. endrin aldehyde
100. heptachlor
101. heptachlor epoxide
102. a-BHC-Alpha
103. b-BHC-Beta
104. r-BHC (lindane)-Gamma
105. g-BHC-Delta
113. toxaphene
114. antimony
116. asbestos (Fibrous)
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

Primary Columbium-Tantalum Subcategory

2. acrolein
3. acrylonitrile
5. benzidene
9. hexachlorobenzene
11. 1,1,1-trichloroethane
13. 1,1-dichloroethane
16. chloroethane
17. DELETED
18. bis (2-chloroethyl) ether
19. 2-chloroethyl vinyl ether (mixed)
21. 2,4,6-trichlorophenol
22. parachlorometa cresol
24. 2-chlorophenol
25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene
28. 3,3'-dichlorobenzidine
29. 1,1-dichloroethylene
31. 2,4-dichlorophenol
32. 1,2-dichloropropane
33. 1,2-dichloropropylene (1,3-dichloropropene)

34. 2,4-dimethylphenol
37. 1,2-diphenylhydrazine
40. 4-chlorophenyl phenyl ether
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-choroethoxy) methane
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
49. DELETED
50. DELETED
52. hexachlorobutadiene
53. hexachlorocyclopentadiene
55. naphthalene
57. 2-nitrophenol
58. 4-nitrophenol
59. 2,4-dinitrophenol
60. 4,6-dinitro-o-cresol
61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine
64. pentachlorophenol
65. phenol
67. butyl benzyl phthalate
69. di-n-octyl phthalate
72. benzo(a)anthracene (1,2-benzanthracene)
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthane (11,12-benzofluoranthene)
76. chrysene
77. acenaphthylene
79. benzo(ghi)perylene (1,11-benzoperylene)
82. dibenzo(a,h)anthracene (1,2,5,6-dibenzanthracene
83. indeno (1,2,3-cd)pyrene
84. pyrene
86. toluene
88. vinyl chloride (chloroethylene)
89. aldrin
90. dieldrin
91. chlordane (technical mixture and metabolites)
92. 4,4'-DDT
93. 4,4'-DDE(p,p'DDX)
94. 4,4'-DDD(p,p'TDE)
95. a-endosulfan-Alpha
96. b-endosulfan-Beta
97. endosulfan sulfate
98. endrin
99. endrin aldehyde
100. heptachlor
101. heptachlor epoxide
102. a-BHC-Alpha
103. B-BHC-Beta
104. r-BHC (lindane)-Gamma
105. delta-BHC
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

Secondary Silver Subcategory

2. acrolein
3. acrylonitrile
5. benzidene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene
12. hexachlorethane
13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
16. chloroethane
17. DELETED
18. bis (2-chloroethyl) ether
19. 2-chloroethyl vinyl ether (mixed)
20. 2-chloronaphthalene
21. 2,4,6-trichlorophenol
22. parachlorometa cresol
24. 2-chlorophenol
25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene
28. 3,3'-dichlorobenzidine
31. 2,4-dichlorophenol
32. 1,2-dichloropropane
33. 1,2-dichloropropylene (1,3-dichloropropene)
34. 2,4-dimethylphenol
35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene
37. 1,2-diphenylhydrazine
39. fluoranthene
40. 4-chlorophenyl phenyl ether
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-choroethoxy) methane
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
48. dichlorobromomethane
49. DELETED
50. DELETED
52. hexachlorobutadiene
53. hexachlorocyclopentadiene
54. isophorone
55. naphthalene
56. nitrobenzene
57. 2-nitrophenol
58. 4-nitrophenol
59. 2,4-dinitrophenol
60. 4,6-dinitro-o-cresol
61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine

64. pentachlorophenol
65. phenol
71. dimethyl phthalate
72. benzo (a)anthracene (1,2-benzanthracene)
73. benzo (a)pyrene (3,4-benzopyrene)
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthane (11,12-benzofluoranthene)
76. chrysene
77. acenaphthylene
79. benzo(ghi)perylene (1,11-benzoperylene)
80. fluorene
82. dibenzo (a,h)anthracene (1,2,5,6-dibenzanthracene)
83. indeno (1,2,3-cd)pyrene
88. vinyl chloride (chloroethylene)
89. aldrin
94. 4,4'-DDD(p,p'TDE)
95. a-endosulfan-Alpha
96. b-endosulfan-Beta
97. endosulfan sulfate
101. heptachlor epoxide
105. g-BHC-Delta
117. beryllium
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

Secondary Lead Subcategory

1. acenaphthene
2. acrolein
3. acrylonitrile
4. benzene
5. benzidene
6. carbon tetrachloride (tetrachloromethane)
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene
10. 1,2-dichloroethane
11. 1,1,1-trichlorethane
12. hexachlorethane
13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
15. 1,1,2,2-tetrachloroethylene
16. chloroethane
17. DELETED
18. bis (2-chloroethyl) ether
19. 2-chloroethyl vinyl ether (mixed)
20. 2-chloronaphthalene
21. 2,4,6-trichlorophenol
22. parachlorometa cresol
24. 2-chlorophenol

25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene
28. 3,3'-dichlorobenzidine
29. 1,1-dichloroethylene
30. 1,2-trans-dichloroethylene
31. 2,4-dichlorophenol
32. 1,2-dichloropropane
33. 1,2-dichloropropylene (1,3-dichloropropene)
34. 2,4-dimethylphenol
35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene
37. 1,2-diphenylhydrazine
38. ethylbenzene
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-choroethoxy) methane
44. methylene chloride (dichloromethane)
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
48. dichlorobromomethane
49. DELETED
50. DELETED
51. chlorodibromomethane
52. hexachlorobutadiene
53. hexachlorocyclopentadiene
54. isophorone
55. naphthalene
57. 2-nitrophenol
58. 4-nitrophenol
59. 2,4-dinitrophenol
60. 4,6-dinitro-o-cresol
61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine
64. pentachlorophenol
65. phenol
67. butyl benzyl phthalate
72. benzo(a)anthracene (1,2-benzanthracene)
73. benzo(a)pyrene (3,4-benzopyrene)
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthene (11,12-benzofluoranthene)
79. benzo(ghi)perylene (1,11-benzoperylene)
80. fluorene
82. dibenzo(a,h)anthracene (1,2,5,6-dibenzanthracene)
83. indeno(1,2,3-cd)pyrene
85. tetrachloroethylene
86. toluene
87. trichloroethylene
88. vinyl chloride (chloroethylene)
89. aldrin

95. a-endosulfan-Alpha
97. endosulfan sulfate
105. g-BHC-Delta
113. toxaphene
116. asbestos (Fibrous)
125. selenium
129. 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

Toxic Pollutants Detected Below the Analytical Quantification Limit

Primary Aluminum Smelting Subcategory

54. isophorone
69. di-n-ocytl phthalate
70. diethyl phthalate
86. toluene
87. trichloroethylene
89. aldrin
90. dieldrin
91. chlordane (technical mixture and metabolites)
92. 4,4'-DDT
93. 4,4'-DDE(p,p'DDX)
94. 4,4'-DDD(p,p'TDE)
95. a-endosulfan-Alpha
96. b-endosulfan-Beta
97. endosulfan sulfate
98. endrin
99. endrin aldehyde
100. heptachlor
101. heptachlor epoxide
102. a-BHC-Alpha
103. b-BHC-Beta
104. r-BHC (lindane)-Gamma
105. g-BHC-Delta
109. PCB-1232 (Arochlor 1232) (a)
110. PCB-1248 (Arochlor 1248) (a)
111. PCB-1260 (Arochlor 1260) (a)
112. PCB-1016 (Arochlor 1016) (a)
113. toxaphene

(a) Reported together.

Secondary Aluminum Subcategory

91. chlordane (technical mixture and metabolites)
92. 4,4'-DDT
93. 4,4'-DDE(p,p'DDX)
98. endrin

99. endrin aldehyde
100. heptachlor
101. heptachlor epoxide
102. a-BHC-Alpha
103. b-BHC-Beta
104. r-BHC (lindane)-Gamma
106. PCB-1242 (Arochlor 1242) (a)
107. PCB-1254 (Arochlor 1254) (a)
108. PCB-1221 (Arochlor 1221) (a)
109. PCB-1232 (Arochlor 1232) (b)
110. PCB-1248 (Arochlor 1248) (b)
111. PCB-1260 (Arochlor 1260) (b)
112. PCB-1016 (Arochlor 1016) (b)
113. toxaphene
121. cyanide (Total)

(a), (b) Reported together.

Primary Electrolytic Copper Refining Subcategory

1. acenaphthene
4. benzene
11. 1,1,1-trichlorethane
15. 1,1,2,2-tetrachloroethane
29. 1,1-dichloroethylene
30. 1,2-trans-dichloroethylene
39. fluoranthene
55. naphthalene
71. dimethyl phthalate
73. benzo (a)pyrene (3,4-benzopyrene)
75. benzo(k)fluoranthane (11,12-benzofluoranthene)
76. chrysene
78. anthracene (a)
81. phenanthrene (a)
84. pyrene
85. tetrachloroethylene
87. trichloroethylene
91. chlordane (technical mixture and metabolites)
92. 4,4'-DDT
93. 4,4'-DDE(p,p'DDX)
95. a-endosulfan-Alpha
96. b-endosulfan-Beta
97. endosulfan sulfate
98. endrin
99. endrin aldehyde
100. heptachlor
101. heptachlor epoxide
102. a-BHC-Alpha
103. b-BHC-Beta

104.	r-BHC (lindane)-Gamma	
106.	PCB-1242 (Arochlor 1242)	(b)
107.	PCB-1254 (Arochlor 1254)	(b)
108.	PCB-1221 (Arochlor 1221)	(b)
109.	PCB-1232 (Arochlor 1232)	(c)
110.	PCB-1248 (Arochlor 1248)	(c)
111.	PCB-1260 (Arochlor 1260)	(c)
112.	PCB-1016 (Arochlor 1016)	(c)

(a), (b), (c) Reported together.

Primary Lead Subcategory

4. benzene
6. carbon tetrachloride (tetrachloromethane)
23. chloroform (trichloromethane)
44. methylene chloride (dichloromethane)

Metallurgical Acid Plants Subcategory

4. benzene
10. 1.2-dichloroethane
14. 1,1,2-trichloroethane
15. 1,1,2,2-tetrachloroethane
39. fluoranthene
49. DELETED
51. chlorodibromomethane
54. isophorone
55. naphthalene
[illegible]4. pentachlorophenol
65. phenol
67. butyl benzyl phthalate
68. di-n-butyl phthalate
69. di-n-octyl phthalate
70. diethyl phthalate
71. dimethyl phthalate
73. benzo (a)pyrene (3,4-benzopyrene)
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthane (11,12-benzofluoranthene)
76. chrysene
80. fluorene
84. pyrene
87. trichloroethylene
90. dieldrin
91. chlordane (technical mixture and metabolites)
92. 4,4'-DDT
93. 4,4'-DDE(p,p'DDX)

94. 4,4'-DDD(p,p'TDE)
96. b-endosulfan-Beta
98. endrin
99. endrin aldehyde
100. heptachlor
101. heptachlor epoxide
103. b-BHC-Beta
104. r-BHC (lindane)-Gamma
106. PCB-1242 (Arochlor 1242) (a)
107. PCB-1254 (Arochlor 1254) (a)
108. PCB-1221 (Arochlor 1221) (a)
109. PCB-1232 (Arochlor 1232) (b)
110. PCB-1248 (Arochlor 1248) (b)
111. PCB-1260 (Arochlor 1260) (b)
112. PCB-1016 (Arochlor 1016) (b)
117. beryllium
121. cyanide (Total)

(a), (b) Reported together.

Primary Tungsten Subcategory

4. benzene
10. 1.2-dichloroethane
15. 1,1,2,2-tetrachloroethane
39. fluoranthene
78. anthracene (a)
81. phenanthrene (a)
84. pyrene
87. trichloroethylene
95. a-endosulfan-Alpha
106. PCB-1242 (Arochlor 1242) (b)
107. PCB-1254 (Arochlor 1254) (b)
108. PCB-1221 (Arochlor 1221) (b)
109. PCB-1232 (Arochlor 1232) (c)
110. PCB-1248 (Arochlor 1248) (c)
111. PCB-1260 (Arochlor 1260) (c)
112. PCB-1016 (Arochlor 1016) (c)

(a), (b), (c) Reported together.

Primary Columbium-Tantalum Subcategory

14. 1,1,2-trichloroethane
15. 1,1,2,2-tetrachloroethane
20. 2-chloronaphthalene
35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene

39. fluoranthene
67. butyl benzyl phthalate
73. benzo (a)pyrene (3,4-benzopyrene)
78. anthracene (a)
80. fluorene
81. phenanthrene (a)
113. toxaphene
121. cyanide (Total)

(a) Reported together.

Secondary Silver Subcategory

7. chlorobenzene
15. 1,1,2,2-tetrachloroethane
51. chlorodibromomethane
78. anthracene (a)
81. phenanthrene (a)
90. dieldrin
91. chlordane (technical mixture and metabolites)
92. 4,4'-DDT
93. 4,4'-DDE(p,p'DDX)
98. endrin
99. endrin aldehyde
100. heptachlor
102. a-BHC-Alpha
103. b-BHC-Beta
104. r-BHC (lindane)-Gamma
113. toxaphene
116. asbestos

(a) Reported together.

Secondary Lead

7. chlorobenzene
40. 4-chlorophenyl phenyl ether
70. diethyl phthalate
78. anthracene (a)
81. phenanthrene (a)
90. dieldrin
91. chlordane (technical mixture and metabolites)
92. 4,4'-DDT
93. 4,4'-DDE(p,p'DDX)
94. 4,4'-DDD(p,p'TDE)
96. b-endosulfan-Beta
98. endrin

99. endrin aldehyde
100. heptachlor
101. heptachlor epoxide
102. a-BHC-Alpha
103. b-BHC-Beta
104. r-BHC (lindane)-Gamma
106. PCB-1242 (Arochlor 1242) (b)
107. PCB-1254 (Arochlor 1254) (b)
108. PCB-1221 (Arochlor 1221) (b)
109. PCB-1232 (Arochlor 1232) (c)
110. PCB-1248 (Arochlor 1248) (c)
111. PCB-1260 (Arochlor 1260) (c)
112. PCB-1016 (Arochlor 1016) (c)

(a), (b), (c) Reported together.

Toxic Pollutants Detected in Amounts Too Small to be Effectively Reduced by Technologies Considered in Preparing this Guideline

Primary Aluminum Smelting Subcategory

4. benzene
23. chloroform (trichloromethane)
44. methylene chloride (dichloromethane)
123. mercury

Secondary Aluminum Subcategory

29. 1,1-dichloroethylene
30. 1,2-trans-dichloroethylene
48. dichlorobromomethane
114. antimony
117. beryllium
123. mercury
125. selenium
126. silver

Primary Electrolytic Copper Refining Subcategory

114. antimony
125. selenium

Primary Lead Subcategory

115. arsenic
117. beryllium
119. chromium (Total)
123. mercury
124. nickel

125. selenium
126. silver

Primary Zinc Subcategory

44. methylene chloride
123. mercury
125. selenium

Metallurgical Acid Plants Subcategory

23. chloroform (trichloromethane)
48. dichlorobromomethane
85. tetrachloroethylene

Primary Tungsten Subcategory

23. chloroform (trichloromethane)
29. 1,1-dichloroethylene
38. ethylbenzene
51. chlorodibromomethane
85. tetrachloroethylene
86. toluene
117. beryllium
121. cyanide (Total)
123. mercury

Primary Columbium-Tantalum Subcategory

4. benzene
48. dichlorobromomethane
54. isophorone
70. diethyl phthalate
117. beryllium
126. silver

Secondary Silver Subcategory

1. acenaphthene
30. 1,2-trans-dichloroethylene
38. ethylbenzene

Secondary Lead Subcategory

23. chloroform (trichloromethane)
47. bromoform (tribromomethane)
56. nitrobenzene
71. dimethyl phthalate
117. beryllium

Toxic Pollutants Detected in the Effluent From Only a Small Number of Sources

Primary Aluminum Smelting Subcategory

20. 2-chloronaphthalene
42. bis(2-chloroisopropyl) ether
55. naphthalene
62. N-nitrosodiphenylamine
65. phenol
66. bis(2-ethylhexyl) phthalate
67. butyl benzyl phthalate
68. di-n-butyl phthalate
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthene (11,12-benzofluoranthene)
83. indeno(1,2,3-cd)pyrene
106. PCB-1242 (Arochlor 1242) (a)
107. PCB-1254 (Arochlor 1254) (a)
108. PCB-1221 (Arochlor 1221) (a)
117. beryllium
126. silver
127. thallium

(a), (b) Reported together.

Secondary Aluminum Subcategory

4. benzene
23. chloroform (trichloromethane)
27. 1,4-dichlorobenzene
39. fluoranthene
44. methylene chloride (dichloromethane)
66. bis(2-ethylhexyl) phthalate
67. butyl benzyl phthalate
68. di-n-butyl phthalate
69. di-n-octyl phthalate
71. dimethyl phthalate
73. benzo (a)pyrene (3,4-benzopyrene)
76. chrysene
77. acenaphthylene
84. pyrene
85. tetrachloroethylene

87. trichloroethylene
115. arsenic
119. chromium (Total)
120. copper
124. nickel
127. thallium

Primary Lead Subcategory

114. antimony
120. copper

Metallurgical Acid Plants Subcategory

6. carbon tetrachloride
13. 1,1-dichloroethane
44. methylene chloride (dichloromethane)
66. bis(2-ethylhexyl) phthalate
78. anthracene (a)
81. phenanthrene (a)
86. toluene
127. thallium

(a) Reported together.

Primary Tungsten Subcategory

47. bromoform (tribromomethane)
66. bis(2-ethylhexyl) phthalate
68. di-n-butyl phthalate
69. di-n-octyl phthalate
76. chrysene
115. arsenic
120. copper
124. nickel
126. silver

Primary Columbium-Tantalum Subcategory

1. acenapthene
6. carbon tetrachloride (tetrachloromethane)
12. hexachlorethane
23. chloroform (trichloromethane)
30. 1,2-trans-dichloroethylene
44. methylene chloride
47. bromoform
56. nitrobenzene

66. bis(2-ethylhexyl) phthalate
68. di-n-butyl phthalate
71. dimethyl phthalate
85. tetrachloroethylene
106. PCB-1242 (Arochlor 1242) (a)
107. PCB-1254 (Arochlor 1254) (a)
108. PCB-1221 (Arochlor 1221) (a)
109. PCB-1232 (Arochlor 1232) (b)
110. PCB-1248 (Arochlor 1248) (b)
111. PCB-1260 (Arochlor 1260) (b)
112. PCB-1016 (Arochlor 1016) (b)
123. mercury

(a), (b) Reported together.

Secondary Silver Subcategory

11. 1,1,1-trichlorethane
23. chloroform (trichloromethane)
44. methylene chloride (dichloromethane)
47. bromoform (tribromomethane)
66. bis(2-ethylhexyl) phthalate
67. butyl benzyl phthalate
68. di-n-butyl phthalate
69. di-n-octyl phthalate
70. diethyl phthalate
84. pyrene
85. tetrachloroethylene
86. toluene
106. PCB-1242 (Arochlor 1242) (a)
107. PCB-1254 (Arochlor 1254) (a)
108. PCB-1221 (Arochlor 1221) (a)
109. PCB-1232 (Arochlor 1232) (b)
110. PCB-1248 (Arochlor 1248) (b)
111. PCB-1260 (Arochlor 1260) (b)
112. PCB-1016 (Arochlor 1016) (b)
123. mercury

(a), (b) Reported together.

Secondary Lead Subcategory

39. fluoranthene
66. bis(2-ethylhexyl) phthalate
68. di-n-butyl phthalate
69. di-n-octyl phthalate
76. chrysene
77. acenaphthylene
84. pyrene
121. cyanide (Total)
123. mercury

Toxic Pollutants Detected But Present Solely as a Result of Their Presence in the Intake Waters

Primary Electrolytic Copper Refining Subcategory

23. chloroform
66. bis(2-ethylhexyl) phthalate
67. butyl benzyl phthalate
68. di-n-butyl phthalate
69. di-n-ocytl phthalate

Table VI-1

LIST OF 129 TOXIC POLLUTANTS

Compound Name

1. acenaphthene
2. acrolein
3. acrylonitrile
4. benzene
5. benzidene
6. carbon tetrachloride (tetrachloromethane)

Chlorinated benzenes (other than dichlorobenzenes)

7. chlorobenzene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene

Chlorinated ethanes (including 1,2-dichloroethane. 1,1,1-trichloroethane and hexachloroethane)

10. 1.2-dichloroethane
11. 1,1,1-trichlorethane
12. hexachlorethane
13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
15. 1,1,2,2-tetrachloroethane
16. chloroethane

Chloroalkyl ethers (chloromethyl, chloroethyl and mixed ethers)

17. bis (chloromethyl) ether
18. bis (2-chloroethyl) ether
19. 2-chloroethyl vinyl ether (mixed)

Chlorinated naphthalene

20. 2-chloronaphthalene

Chlorinated phenols (other than those listed elsewhere; includes trichlorophenols and chlorinated cresols)

21. 2,4,6-trichlorophenol
22. parachlorometa cresol
23. chloroform (trichloromethane)
24. 2-chlorophenol

Table VI-1 (Continued)

LIST OF 129 TOXIC POLLUTANTS

Dichlorobenzenes

25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene

Dichlorobenzidine

28. 3,3'-dichlorobenzidine

Dichloroethylenes (1,1-dichloroethylene and 1,2-dichloroethylene)

29. 1,1-dichloroethylene
30. 1,2-trans-dichloroethylene
31. 2,4-dichlorophenol

Dichloropropane and dichloropropene

32. 1,2-dichloropropane
33. 1,2-dichloropropylene (1,3-dichloropropene)
34. 2,4-dimethylphenol

Dinitrotoluene

35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene
37. 1,2-diphenylhydrazine
38. ethylbenzene
39. fluoranthene

Haloethers (other than those listed elsewhere)

40. 4-chlorophenyl phenyl ether
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-choroethoxy) methane

Halomethanes (other than those listed elsewhere)

44. methylene chloride (dichloromethane)
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)

Table VI-1 (Continued)

LIST OF 129 TOXIC POLLUTANTS

Halomethanes (Cont.)

47. bromoform (tribromomethane)
48. dichlorobromomethane
49. trichlorofluoromethane
50. dichlorodifluoromethane
51. chlorodibromomethane
52. hexachlorobutadiene
53. hexachlorocyclopentadiene
54. isophorone
55. naphthalene
56. nitrobenzene

Nitrophenols (including 2,4-dinitrophenol and dinitrocresol)

57. 2-nitrophenol
58. 4-nitrophenol
59. 2,4-dinitrophenol
60. 4,6-dinitro-o-cresol

Nitrosamines

61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine
64. pentachlorophenol
65. phenol

Phthalate esters

66. bis(2-ethylhexyl) phthalate
67. butyl benzyl phthalate
68. di-n-butyl phthalate
69. di-n-octyl phthalate
70. diethyl phthalate
71. dimethyl phthalate

Polynuclear aromatic hydrocarbons

72. benzo (a)anthracene (1,2-benzanthracene)
73. benzo (a)pyrene (3,4-benzopyrene)
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthane (11,12-benzofluoranthene)

Table VI-1 (Continued)

LIST OF 129 TOXIC POLLUTANTS

Polynuclear aromatic hydrocarbons (Cont.)

76. chrysene
77. acenaphthylene
78. anthracene
79. benzo(ghi)perylene (1,11-benzoperylene)
80. fluorene
81. phenanthrene
82. dibenzo (a,h)anthracene (1,2,5,6-dibenzanthracene)
83. indeno (1,2,3-cd)pyrene (w,e,-o-phenylenepyrene)
84. pyrene
85. tetrachloroethylene
86. toluene
87. trichloroethylene
88. vinyl chloride (chloroethylene)

Pesticides and metabolites

89. aldrin
90. dieldrin
91. chlordane (technical mixture and metabolites)

DDT and metabolites

92. 4,4'-DDT
93. 4,4'-DDE(p,p'DDX)
94. 4,4'-DDD(p,p'TDE)

Polychlorinated biphenyls (PCB's)

Endosulfan and metabolites

95. a-endosulfan-Alpha
96. b-endosulfan-Beta
97. endosulfan sulfate

Endrin and metabolites

98. endrin
99. endrin aldehyde

Heptachlor and metabolies

100. heptachlor
101. heptachlor epoxide

Table VI-1 (Continued)

LIST OF 129 TOXIC POLLUTANTS

Hexachlorocyclohexane (all isomers)

102. a-BHC-Alpha
103. b-BHC-Beta
104. r-BHC (lindane)-Gamma
105. g-BHC-Delta
106. PCB-1242 (Arochlor 1242)
107. PCB-1254 (Arochlor 1254)
108. PCB-1221 (Arochlor 1221)
109. PCB-1232 (Arochlor 1232)
110. PCB-1248 (Arochlor 1248)
111. PCB-1260 (Arochlor 1260)
112. PCB-1016 (Arochlor 1016)

Metals and Cyanide, and Asbestos

114. antimony
115. arsenic
116. asbestos (Fibrous)
117. beryllium
118. cadmium
119. chromium (Total)
120. copper
121. cyanide (Total)

Metals and Cyanide, and Asbestos (Cont.)

122. lead
123. mercury
124. nickel
125. selenium
126. silver
127. thallium
128. zinc

Other

113. toxaphene
129. 2,3,7,8-tetra chlorodibenzo-p-dioxin (TCDD)

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

This section describes the treatment techniques currently used or available to remove or recover wastewater pollutants normally generated by the nonferrous metals manufacturing industrial point source category. Included are discussions of individual end-of-pipe treatment technologies and in-plant technologies. These treatment technologies are widely used in this category and many industrial categories; therefore, data and information to support their effectiveness have been drawn from a wide range of sources and data bases.

END-OF-PIPE TREATMENT TECHNOLOGIES

Individual recovery and treatment technologies are described herein which are used or are suitable for use in treating wastewater discharges from nonferrous metals manufacturing facilities. Each description includes a functional description and discussions of application and performance, advantages and limitations, operational factors (reliability, maintainability, solid waste aspects), and demonstration status. The treatment processes described include both technologies presently demonstrated within the nonferrous metals manufacturing category, and technologies demonstrated in treatment of similar wastewater in other industries. These technologies will be evaluated in the appropriate subcategory supplements as they relate to specific nonferrous metals manufacturing subcategories.

Nonferrous metals manufacturing wastewater streams characteristically contain treatable concentrations of toxic metals. The toxic metals antimony, arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc are found in nonferrous metals manufacturing wastewater streams at treatable concentrations. Aluminum, ammonia, cyanide, fluoride, and some toxic organics also may be present. These are the most significant wastewater pollutants in this category.

The most effective technology for metals removal is chemical precipitation, sedimentation, and filtration. Most metals are effectively removed by precipitation of metal hydroxides or carbonates utilizing the reaction with lime, sodium hydroxide, or sodium carbonate. For some metals, improved removal is provided by the use of sodium sulfide or ferrous sulfide to precipitate the pollutants as sulfide compounds.

Discussion of end-of-pipe treatment technologies is divided into three parts: the major technologies; the effectiveness of major technologies; and minor end-of-pipe technologies.

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MAJOR TECHNOLOGIES

In Sections IX, X, XI, and XII of each of the subcategory supplements, the rationale for selecting treatment systems is discussed. The individual technologies used in the system are described here. The major end-of-pipe technologies considered are: activated alumina, ammonia stripping, carbon adsorption, chemical precipitation of dissolved metals, cyanide precipitation, granular bed filtration, pressure filtration, settling of suspended solids, and skimming of oil. In practice, precipitation of metals and settling of the resulting precipitates is often a unified two-step operation. Suspended solids originally present in raw wastewaters are not appreciably affected by the precipitation operation and are removed with the precipitated metals in the settling operations. Settling operations can be evaluated independently of hydroxide or other chemical precipitation operations, but hydroxide and other chemical precipitation operations can only be evaluated in combination with a solids removal operation.

Activated Alumina Adsorption

Application, Performance, Advantages and Limitations. Activated alumina adsorbs arsenic and fluorides. Alumina's removal efficiency depends on the wastewater characteristics. High concentrations of alkalinity or chloride and high pH reduce activated alumina's capacity to adsorb. This reduction in adsorptive capacity is due to the alkalinity-causing (e.g., hydroxides, carbonates, etc.) and chlorine anions competing with arsenic and fluoride ions for removal sites on the alumina.

While chemical precipitation (as discussed on p. 221) can reduce fluoride to less than 14 mg/l by formation of calcium fluoride, activated alumina can reduce fluoride levels to below 1.0 mg/l on a long-term basis. An initial concentration of 30 mg/l of fluoride can be reduced by as much as 85 to 99+ percent. Influent arsenic concentrations of 0.3 to 10 mg/l can be reduced by 85 to 99+ percent. However, some complex forms of fluoride are not removed by activated alumina. Caustic, sulfuric acid, hydrochloric acid, and alum are used to chemically regenerate activated alumina.

Operational Factors--Reliability and Maintainability: Activated alumina has been used at potable water treatment plants for many years. Furthermore, the equipment is similar to that found in ion-exchange water softening plants which are commonly used in industry to prepare boiler water.

Demonstration Status. The use of activated alumina has not been reported by any nonferrous metals manufacturing plants nor is it widely applied in any other industrial categories. High capital and operation costs generally limit the wide application of this process in industrial applications.

Ammonia Steam Stripping

Ammonia, often used as a process reagent, dissolves in water to an extent governed by the partial pressure of the gas in contact with the liquid. The ammonia may be removed from process wastewaters by stripping with air or steam.

Air stripping takes place in a packed or lattice tower; air is blown through the packed bed or lattice, over which the ammonia-laden stream flows. Usually, the wastewater is heated prior to delivery to the tower, and air is used at ambient temperature.

The term "ammonia steam stripping" refers to the process of desorbing aqueous ammonia by contacting the liquid with a sufficient amount of ammonia-free steam. The steam is introduced countercurrent to the wastewater to maximize removal of ammonia. The operation is commonly carried out in packed bed or tray columns, and the pH is adjusted to 12 or more with lime. Simple tray designs (such as disk and doughnut trays) are used in steam stripping because of the presence of appreciable suspended solids and the scaling produced by lime. These allow easy cleaning of the tower, at the expense of somewhat lower steam water contact efficiency, necessitating the use of more trays for the same removal efficiency.

Application and Performance. The evaporation of water and the volatilization of ammonia generally produces a drop in both temperature and pH, which ultimately limit the removal of ammonia in a single air stripping tower. However, high removals are favored by:

1. High pH values, which shift the equilibrium from ammonium toward free ammonia;

2. High temperature, which decreases the solubility of ammonia in aqueous solutions; and

3. Intimate and extended contact between the wastewater to be stripped and the stripping gas.

Of these factors, pH and temperature are generally more cost-effective to optimize than increasing contact time by an increase in contact tank volume or recirculation ratio. The temperature will, to some extent, be controlled by the climatic conditions; the pH of the wastewater can be adjusted to assure optimum stripping.

Steam stripping offers better ammonia removal (99 percent or better) than air stripping for high-ammonia wastewaters found in the primary columbium-tantalum, secondary silver, and primary tungsten subcategories of this category. The performance of an ammonia stripping column is influenced by a number of important variables that are associated with the wastewater being treated and column design. Brief discussions of these variables follow.

Wastewater pH: Ammonia in water exists in two forms, NH_3 and NH_4^+, the distribution of which is pH dependent. Since only the molecular form of ammonia (NH_3) can be stripped, increasing the fraction of NH_3 by increasing the pH enhances the rate of ammonia desorption.

Column temperature: The temperature of the stripping column affects the equilibrium between gaseous and dissolved ammonia, as well as the equilibrium between the molecular and ionized forms of ammonia in water. An increase in the temperature reduces the ammonia solubility and increases the fraction of aqueous ammonia that is in the molecular form, both exhibiting favorable effects on the desorption rate.

Steam rate: The rate of ammonia transfer from the liquid to gas phase is directly proportional to the degree of ammonia undersaturation in the desorbing gas. Increasing the rate of steam supply, therefore, increases undersaturation and ammonia transfer.

Column design: A properly designed stripper column achieves uniform distribution of the feed liquid across the cross section of the column, rapid renewal of the liquid-gas interface, and extended liquid-gas contacting area and time.

Steam stripping can recover significant quantities of reagent ammonia from wastewaters containing extremely high initial ammonia concentrations, which partially offsets the capital and energy costs of the technology.

Advantages and Limitations. Strippers are widely used in industry to remove a variety of materials, including hydrogen sulfide and volatile organics as well as ammonia, from aqueous streams. The basic techniques have been applied both in process and in wastewater treatment applications and are well understood. The use of steam strippers with and without pH adjustment is standard practice for the removal of hydrogen sulfide and ammonia in the petroleum refining industry and has been studied extensively in this context. Air stripping has treated municipal and industrial wastewater and is recognized as an effective technique of broad applicability. Both air and steam stripping have successfully treated ammonia-laden wastewater, both within the nonferrous metals manufacturing category or for similar wastes in closely related industries.

The major drawback of air stripping is the low efficiency in cold weather and the possibility of freezing within the tower. Because lime may cause scaling problems and the types of towers used in air stripping are not easily cleaned, caustic soda is generally employed to raise the feed pH. Air stripping simply transfers the ammonia from one medium to another, whereas, steam stripping allows for recovery and, if so desired, reuse of ammonia. Four primary tungsten plants use steam stripping to recover ammonia from process wastewater and reuse the ammonia in the manufacture of ammonium paratungstate. The two major limitations of steam strippers are the critical column design required for proper operation and the operational problems associated with fouling of the packing material.

Operational Factors. Reliability and Maintainability: Strippers are relatively easy to operate. The most complicated part of a steam stripper is the boiler. Periodic maintenance will prevent unexpected shutdowns of the boiler.

Packing fouling interferes with the intimate contacting of liquid-gas, thus decreasing the column efficiency, and eventually leads to flooding. The stripper column is periodically taken out of service and cleaned with acid and water with air sparging. Column cutoff is predicated on a maximum allowable pressure drop across the packing of maximum "acceptable" ammonia content in the stripper bottoms. Although packing fouling may not be completely avoidable due to endothermic $CaSO_4$ precipitation, column runs could be prolonged by a preliminary treatment step designed to remove suspended solids originally present in the feed and those precipitated after lime addition.

Demonstration Status. Steam stripping has proved to be an efficient, reliable process for the removal of ammonia from many types of industrial wastewaters that contain high concentrations of ammonia. Industries using ammonia steam stripping technology include the fertilizer industry, iron and steel, petroleum refining, organic chemicals manufacturing, and nonferrous metals manufacturing. One plant in the secondary aluminum subcategory, one plant in the secondary lead subcategory, two plants in the primary columbium-tantalum subcategory, and four plants in the primary tungsten subcategory reported steam stripping in-place.

Carbon Adsorption

The use of activated carbon to remove dissolved organics from water and wastewater is a well demonstrated technology. It is one of the most efficient organic removal processes available. This sorption process is reversible, allowing activated carbon to be regenerated for reuse by the application of heat and steam or solvent. Activated carbon has also proved to be an effective adsorbent for many toxic metals, including mercury. Regeneration of carbon which has adsorbed significant metals; however, may be difficult.

The term activated carbon applies to any amorphous form of carbon that has been specially treated to give high adsorption capacities. Typical raw materials include coal, wood, coconut shells, petroleum base residues, and char from sewage sludge pyrolysis. A carefully controlled process of dehydration, carbonization, and oxidation yields a product which is called activated carbon. This material has a high capacity for adsorption due primarily to the large surface area available for adsorption, 500 to 1,500 m^2/gm, resulting from a large number of internal pores. Pore sizes generally range from 10 to 100 angstroms in radius.

Activated carbon removes contaminants from water by the process of adsorption, or the attraction and accumulation of one substance on the surface of another. Activated carbon preferentially adsorbs organic compounds over other species and, because of this selectivity, is particularly effective in removing organic compounds from aqueous solution.

Carbon adsorption requires preliminary treatment to remove excess suspended solids, oils, and greases. Suspended solids concentrations in the influent should be reduced to minimize backwash requirements.

Oil and grease concentrations should also be reduced. High concentrations of dissolved organic material in the influent may cause problems with thermal carbon reactivation (i.e., scaling and loss of activity) unless appropriate preventive steps are taken. Such steps might include pH control, softening, or the use of an acid wash on the carbon prior to reactivation.

Activated carbon is available in both powdered and granular form. A flow diagram of activated carbon treatment and regeneration is shown in Figure VII-1. A schematic of an individual adsorption column is shown in Figure VII-2. Powdered carbon is less expensive per unit weight and may have slightly higher adsorption capacity, but it is more difficult to handle and to regenerate.

Application and Performance. Isotherm tests have indicated that activated carbon is very effective in adsorbing 65 percent of the toxic organic pollutants and is reasonably effective for another 22 percent. Specifically, activated carbon is very effective in removing polynuclear aromatic compounds, 14 of which are classified as toxic pollutants.

Advantages and Limitations. The major benefits of carbon treatment include applicability to a wide variety of organics and high removal efficiency. Inorganics such as cyanide, chromium, and mercury are also removed effectively. Variations in concentration and flow rate are well tolerated. The system is compact, and recovery of adsorbed materials is sometimes practical. However, destruction of adsorbed compounds often occurs during thermal regeneration. If carbon cannot be thermally regenerated, it must be disposed of along with any adsorbed pollutants. The capital and operating costs of thermal regeneration are relatively high. Cost surveys show that thermal regeneration is generally economical when carbon usage exceeds about 650 lbs/day. Carbon cannot remove low molecular weight or highly soluble organics.

Operational Factors. Reliability: This system should be very reliable with any upstream protection necessary from solids or oil and grease and proper operation and maintenance procedures.

Maintainability: This system requires periodic regeneration or replacement of spent carbon and is dependent upon raw waste load and process efficiency.

Solid Waste Aspects: Solid waste from this process is contaminated activated carbon that requires disposal unless the carbon is thermally regenerated. There is some periodic disposal of spent carbon required with thermal regeneration; however, the frequency and amount disposed is significantly smaller.

Demonstration Status. Carbon adsorption systems have been demonstrated to be practical and economical in reducing COD, BOD, and related parameters in secondary municipal and industrial wastewaters; in removing polynuclear aromatic compounds from specific industrial wastewaters (e.g., iron and steel); in removing and recovering certain organics from wastewaters; and in the removing, and sometimes recovering, of selected inorganic chemicals from aqueous waste streams. Carbon adsorption is a viable and economic recovery process for organic waste streams containing up to 1 to 5 percent of refractory or toxic organics. Its applicability for removal of inorganics such as metals has also been demonstrated. None of the plants in the nonferrous metals manufacturing category reported having activated carbon technology in place.

Chemical Precipitation

Dissolved toxic metal ions and certain anions may be chemically precipitated for removal by physical means such as sedimentation, filtration, or centrifugation. Several reagents which are commonly used to effect this precipitation are described below.

1. Alkaline compounds such as lime or sodium hydroxide may be used to precipitate many toxic metal ions as metal hydroxides. Lime also may precipitate phosphates as insoluble calcium phosphate and fluorides as calcium fluoride.

2. Both "soluble" sulfides such as hydrogen sulfide or sodium sulfide and "insoluble" sulfides such as ferrous sulfide may be used to precipitate many heavy metal ions as insoluble metal sulfides.

3. Ferrous sulfate, zinc sulfate, or both (as is required) may be used to precipitate cyanide as a ferro or zinc ferricyanide complex.

4. Carbonate precipitates may be used to remove metals either by direct precipitation using a carbonate reagent such as calcium carbonate or by converting hydroxides into carbonates using carbon dioxide.

These treatment chemicals may be added to a flash mixer or rapid mix tank, to a presettling tank, or directly to a clarifier or other settling device. Because metal hydroxides tend to be colloidal in nature, coagulating agents may also be added to facilitate settling. After the solids have been removed, final pH adjustment may be required to reduce the high pH created by the alkaline treatment chemicals.

Chemical precipitation as a mechanism for removing metals from wastewater is a complex process of at least two steps - precipitation of the unwanted metals and removal of the precipitate. Some small amount of metal will remain dissolved in the wastewater after complete precipitation; the amount depends on the treatment chemicals used and related factors. The effectiveness of this method of removing any specific metal depends on the fraction of the specific metal in the raw waste (and hence in the precipitate) and the effectiveness of suspended solids removal. In specific instances, a sacrificial ion such as iron or aluminum may be added to aid in the precipitation process and reduce the fraction of a specific metal in the precipitate.

Application and Performance. Chemical precipitation is used in nonferrous metals manufacturing for precipitation of dissolved metals. It can be used to remove metal ions such as aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, mercury, selenium, silver, thallium, and zinc. The process is also applicable to any substance that can be transformed into an insoluble form such as fluorides, phosphates, soaps, and sulfides, among others. Because it is simple and effective, chemical precipitation is extensively used for industrial wastewater treatment.

The performance of chemical precipitation depends on several variables. The most important factors controlling precipitation effectiveness are:

1. Maintenance of an alkaline pH throughout the precipitation reaction and subsequent settling;

2. Addition of a sufficient excess of treatment ions to drive the precipitation reaction to completion;

3. Addition of an adequate supply of sacrificial ions (such as iron or aluminum) to ensure precipitation and removal of specific target ions; and

4. Effective removal of precipitated solids (see appropriate technologies discussed under "Solids Removal").

Control of pH. Irrespective of the solids removal technology used, proper control of pH is absolutely essential for favorable performance of precipitation-sedimentation technologies. This is clearly illustrated by solubility curves for selected metals hydroxides and sulfides shown in Figure VII-3, and by plotting effluent zinc concentrations against pH as shown in Figure VII-4. Figure VII-3 was obtained from Development Document for the Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Zinc Segment of the Nonferrous Metals Manufacturing Point Source Category, U.S. EPA, EPA 440/1-74/033, November, 1974. Figure VII-4 was plotted from the sampling data from several facilities with metal finishing operations. It is partially illustrated by data obtained from three consecutive days of sampling at one copper forming plant (47432) as displayed in Table VII-1. Flow through this system is approximately 49,263 l/hr (13,000 gal/hr).

This treatment system uses lime precipitation (pH adjustment) followed by coagulant addition and sedimentation. Samples were taken before (in) and after (out) the treatment system. The best treatment for removal of copper and zinc was achieved on day one, when the pH was maintained at a satisfactory level. The poorest treatment was found on the second day, when the pH slipped to an unacceptably low level and intermediate values were achieved on the third day, when pH values were less than desirable but in between the first and second days.

Sodium hydroxide is used by one battery manufacturing facility (plant 439) for pH adjustment and chemical precipitation, followed by settling (sedimentation and a polishing lagoon) of precipitated solids. Samples were taken prior to caustic addition and following the polishing lagoon. Flow through the system is approximately 22,700 l/hr (6,000 gal/hr). Metals removal data for this system are presented in Table VII-2. Effluent pH was controlled within the range of 8.6 to 9.3, and while raw waste loadings were not unusually high, most toxic metals were removed to very low concentrations.

Plant 40063, a porcelain enameling facility with a metal-bearing wastewater, exemplifies efficient operation of a chemical precipitation and settling system. Table VII-3 shows sampling data from this system, which uses lime and sodium hydroxide for pH adjustment, chemical precipitation, polyelectrolyte flocculant addition, and sedimentation. Samples were taken of the raw waste influent to the system and of the clarifier effluent. Flow through the system is approximately 19,000 l/hr (5,000 gal/hr).

At this plant, effluent TSS levels were below 15 mg/l on each day, despite average raw waste TSS concentrations of over 3,500 mg/l. Effluent pH was maintained at approximately 8, lime addition was sufficient to precipitate the dissolved metal ions, and the flocculant addition and clarifier retention served to remove effectively the precipitated solids.

Sulfide precipitation is sometimes used to precipitate metals resulting in improved metals removals. Most metal sulfides are less soluble than hydroxides and the precipitates are frequently more effectively removed from water. Solubilities for selected metal hydroxide, carbonate, and sulfide precipitates are shown in Table VII-4 (Source: Lange's Handbook of Chemistry). Sulfide precipitation is particularly effective in removing specific metals such as silver and mercury. Sampling data from three industrial plants using sulfide precipitation appear in Table VII-5. The data were obtained from three sources:

1. Summary Report, Control and Treatment Technology for the Metal Finishing Industry: Sulfide Precipitation, U.S. EPA, EPA No. 625/8/80-003, 1979.

2. Industrial Finishing, Vol. 35, No. 11, November, 1979.

3. Electroplating sampling data from plant 27045.

In all cases except iron, effluent concentrations are below 0.1 mg/l and in many cases below 0.04 mg/l for the three plants studied.

Sampling data from several chlorine-caustic manufacturing plants using sulfide precipitation demonstrate effluent mercury concentrations varying between 0.009 and 0.03 mg/l. As shown in Figure VII-5, the solubilities of PbS and Ag_2S are lower at alkaline pH levels than either the corresponding hydroxides or other sulfide compounds. This implies that removal performance for lead and silver sulfides should be comparable to or better than that for the heavy metal hydroxides. Bench scale tests on several types of metal finishing and manufacturing wastewater indicate that metals removal to concentrations of less than 0.05 mg/l and in some cases less than 0.01 mg/l are common in systems using sulfide precipitation followed by clarification. Some of the bench scale data, particularly in the case of lead, do not support such low effluent concentrations. However, lead is consistently removed to very low concentrations (less than 0.02 mg/l) in systems using hydroxide and carbonate precipitation and sedimentation.

Of particular interest is the ability of sulfide to precipitate hexavalent chromium (Cr+6) without prior reduction to the trivalent state as is required in the hydroxide process. When ferrous sulfide is used as the precipitant, iron and sulfide act as reducing agents for the hexavalent chromium according to the reaction:

$$CrO_3 + FeS + 3H_2O \rightarrow Fe(OH)_3 + Cr(OH)_3 + S$$

The sludge produced in this reaction consists mainly of ferric hydroxides, chromic hydroxides, and various metallic sulfides. Some excess hydroxyl ions are generated in this process, possibly requiring a downward readjustment of pH.

Based on the available data, Table VII-6 shows the minimum reliably attainable effluent concentrations for sulfide precipitation-sedimentation systems. These values are used to calculate performance predictions of sulfide precipitation-sedimentation systems.

Carbonate precipitation is sometimes used to precipitate metals, especially where precipitated metals values are to be recovered. The solubility of most metal carbonates is intermediate between hydroxide and sulfide solubilities; in addition, carbonates form easily filtered precipitates.

Carbonate ions appear to be particularly useful in precipitating lead. Sodium carbonate has been observed being added at treatment to improve lead precipitation and removal in some industrial plants. The lead hydroxide and lead carbonate solubility curves displayed in Figure VII-5 ("Heavy Metals Removal," by Kenneth Lanovette, Chemical Engineering/Deskbook Issue, Oct. 17, 1977) explain this phenomenon.

Co-precipitation with Iron - The presence of substantial quantities of iron in metal-bearing wastewaters before treatment has been shown to improve the removal of toxic metals. In some cases this iron is an integral part of the industrial wastewater; in other cases iron is deliberately added as a preliminary or first step of treatment. The iron functions to improve toxic metal removal by three mechanisms: the iron co-precipitates with toxic metals forming a stable precipitate which desolubilizes the toxic metal; the iron improves the settleability of the precipitate; and the large amount of iron reduces the fraction of toxic metal in the precipitate. Co-precipitation with iron has been practiced for many years; incidentally, when iron was a substantial constituent of raw wastewater and, intentionally, when iron salts were added as a coagulant aid. Aluminum or mixed iron-aluminum salt also have been used.

Co-precipitation using large amounts of ferrous iron salts is known as ferrite co-precipitation because magnetic iron oxide or ferrite is formed. The addition of ferrous salts (sulfate) is followed by alkali precipitation and air oxidation. The resultant precipitate is easily removed by filtration and may be removed magnetically. Data illustrating the performance of ferrite co-precipitation is shown in Table VII-7.

Advantages and Limitations

Chemical precipitation has proven to be an effective technique for removing many pollutants from industrial wastewater. It operates at ambient conditions and is well suited to automatic control. The use of chemical precipitation may be limited because of interference by chelating agents, because of possible chemical interference of mixed wastewaters and treatment chemicals, or because of the potentially hazardous situation involved with the storage and handling of those chemicals. Lime is usually added as a slurry when used in hydroxide precipitation. The slurry must be kept well mixed and the addition lines periodically checked to prevent blocking of the lines, which may result from a buildup of solids. Also, hydroxide precipitation usually makes recovery of the precipitated metals difficult, because of the heterogeneous nature of most hydroxide sludges.

The major advantage of the sulfide precipitation process is that the extremely low solubility of most metal sulfides promotes very high metal removal efficiencies; the sulfide process also has the ability to remove chromates and dichromates without preliminary reduction of the chromium to its trivalent state. In addition, sulfide can precipitate metals complexed with most complexing agents. The process demands care, however, in maintaining the pH of the solution at approximately 10 in order to prevent the generation of toxic hydrogen sulfide gas. For this reason, ventilation of the treatment tanks may be a necessary precaution in most installations. The use of insoluble sulfides reduces the problem of hydrogen sulfide evolution. As with hydroxide precipitation, excess sulfide ion must be present to drive the precipitation reaction to completion. Since the sulfide ion itself is toxic, sulfide addition must be carefully controlled to maximize heavy metals precipitation with a minimum of excess sulfide to avoid the necessity of post treatment. At very high excess sulfide concentrations and high pH, soluble mercury-sulfide compounds also may be formed. Where excess sulfide is present, aeration of the effluent stream can aid in oxidizing residual sulfide to the less harmful sodium sulfate (Na_2SO_4). The cost of sulfide precipitants is high in comparison with hydroxide precipitants, and disposal of metallic sulfide sludges may pose problems. An essential element in effective sulfide precipitation is the removal of precipitated solids from the wastewater and proper disposal in an appropriate site. Sulfide precipitation will also generate a higher volume of sludge than hydroxide precipitation, resulting in higher disposal and dewatering costs. This is especially true when ferrous sulfide is used as the precipitant.

Sulfide precipitation may be used as a polishing treatment after hydroxide precipitation-sedimentation. This treatment configuration may provide the better treatment effectiveness of sulfide precipitation while minimizing the variability caused by changes in raw waste and reducing the amount of sulfide precipitant required.

Operational Factors. Reliability: Alkaline chemical precipitation is highly reliable, although proper monitoring and control are required. Sulfide precipitation systems provide similar reliability.

Maintainability: The major maintenance needs involve periodic upkeep of monitoring equipment, automatic feeding equipment, mixing equipment, and other hardware. Removal of accumulated sludge is necessary for efficient operation of precipitation-sedimentation systems.

Solid Waste Aspects: Solids which form the precipitate are removed in a subsequent treatment step. Ultimately, these solids require proper disposal.

Demonstration Status. Chemical precipitation of metal hydroxides is a classic waste treatment technology used by at least 60 nonferrous metals manufacturing plants for wastewater treatment. Chemical precipitation of metals in the carbonate form alone has been found to be feasible and is commercially used to permit metals recovery and water reuse. Full scale commercial sulfide precipitation units are in operation at numerous installations in other categories (e.g., metal finishing) and at one Swedish smelter. As noted earlier, sedimentation to remove precipitates is discussed separately.

Cyanide Precipitation

Cyanide precipitation, although a method for treating cyanide in wastewaters, does not destroy cyanide. The cyanide is retained in the sludge that is formed. Reports indicate that during exposure to sunlight the cyanide complexes can break down and form free cyanide. For this reason the sludge from this treatment method must be disposed of carefully.

Cyanide may be precipitated and settled out of wastewaters by the addition of zinc sulfate or ferrous sulfate. In the presence of iron, cyanide will form extremely stable cyanide complexes. The addition of zinc sulfate or ferrous sulfate forms zinc ferrocyanide or ferro- and ferricyanide complexes.

Adequate removal of the precipitated cyanide requires that the pH be kept at 9 and an appropriate detention time be maintained. A study has shown that the formation of the complex is very dependent on pH. At pH's of 8 and 10 the residual cyanide concentrations measured are twice those of the same reaction carried out at a pH of 9. Removal efficiencies also depend heavily on the retention time allowed. The formation of the complexes takes place rather slowly. Depending upon the excess amount of zinc sulfate or ferrous sulfate added, at least a 30-minute retention time should be allowed for the formation of the cyanide complex before continuing on to the clarification stage.

One experiment with an initial concentration of 10 mg/l of cyanide showed that 98 percent of the cyanide was complexed 10 minutes after the addition of ferrous sulfate at twice the theoretical amount necessary. Interference from other metal ions, such as cadmium, might result in the need for longer retention times.

Table VII-8 presents data from three coil coating plants using well-operated cyanide precipitation treatment. These data form the basis for the concentration achievable by this technology. Of these three plants, one plant (Plant 1057) also does aluminum forming. A fourth plant was visited for the purpose of observing plant testing of the cyanide precipitation system. Specific data from this facility are not included because: (1) the pH was usually well below the optimum level of 9.0; (2) the historical treatment data were not obtained using the standard cyanide analysis procedure; and (3) paired untreated and treated data were not made available by the plant. The available data presented in Table VII-11 indicate that the raw waste cyanide concentration was in the range of 0.12 to 3.28 mg/l, the pH 7.5; and treated cyanide concentration was from 0.024 to 0.14. For this reason, we selected the average of these data, 0.07, as the long-term performance concentration achievable by this technology.

Plant 1057 allowed a 27-minute retention time for the formation of the complex. The retention time for the other plants is not known. The data suggest that over a wide range of cyanide concentration in the raw waste, the concentration of cyanide can be reduced in the effluent stream to under 0.07 mg/l on a long-term basis.

Application and Performance. Cyanide precipitation can be used when cyanide destruction is not feasible because of the presence of cyanide complexes which are difficult to destroy. Effluent concentrations of cyanide well below 0.07 mg/l are possible.

Advantages and Limitations. Cyanide precipitation is an inexpensive method of treating cyanide. Problems may occur when metal ions interfere with the formation of the complexes.

Demonstration Status. Although no plants currently use cyanide precipitation to treat nonferrous metals manufacturing wastewaters, it is used in at least six coil coating plants.

Granular Bed Filtration

Filtration occurs in nature as the surface ground waters are cleansed by sand. Silica sand, anthracite coal, and garnet are common filter media used in water treatment plants. These three media are usually supported by gravel. The media may be used singly or in combination. Multimedia filters may be arranged to maintain relatively distinct layers by virtue of balancing the forces of gravity, flow and buoyancy on the individual particles. This is accomplished by selecting appropriate filter loading rates (l/sq m-hr), media grain size, and bed density.

Granular bed filters are classified in terms of filtration rate, filter media, flow pattern, or method of pressurization. Traditional rate classifications are slow sand, rapid sand, and high rate mixed media. In the slow sand filter, flux or hydraulic loading is relatively low, and removal of collected solids to clean the filter is therefore relatively infrequent. The filter is often cleaned by scraping off the inlet face (top) of the sand bed. In the higher rate filters, cleaning is frequent and is accomplished by a periodic backwash, opposite to the direction of normal flow.

A filter may use a single medium such as sand or diatomaceous earth (Figure VII-6a), but dual (Figure VII-6d) and mixed (multi- or multiple) media (Figure VII-6e) filters allow higher flow rates and efficiencies. The dual media filter usually consists of a fine bed of sand under a coarser bed of anthracite coal. The coarse coal removes most of the influent solids, while the fine sand performs a polishing function. At the end of the backwash, the fine sand settles to the bottom because it is denser than the coal, and the filter is ready for normal operation. The mixed media filter operates on the same principle, with the finer, denser media at the bottom and the coarser, less dense media at the top. The usual arrangement is garnet at the bottom (outlet end) of the bed, sand in the middle, and anthracite coal at the top. Some mixing of these layers occurs and is, in fact, desirable.

The flow pattern is usually top-to-bottom, but other patterns are sometimes used. Upflow filters (Figure VII-6b) and horizontal filters are sometimes used. In a biflow filter (Figure VII-6c), the influent enters both the top and the bottom and exits laterally. The advantage of an upflow filter is that with an upflow backwash the particles of a single filter medium are distributed and maintained in the desired coarse-to-fine (bottom-to-top) arrangement. The disadvantage is that the bed tends to become fluidized, which lowers filtration efficiency. The biflow design is an attempt to overcome this problem.

The classic granular bed filter operates by gravity flow; however, pressure filters are fairly widely used. They permit higher solids loadings before cleaning and are advantageous when the filter effluent must be pressurized for further downstream treatment. In addition, pressure filter systems are often less costly for low to moderate flow rates.

Figure VII-7 depicts a high rate, dual media, gravity downflow granular bed filter, with self-stored backwash. Both filtrate and backwash are piped around the bed in an arrangement that permits gravity upflow of the backwash, with the stored filtrate serving as backwash. Addition of the indicated coagulant and polyelectrolyte usually results in a substantial improvement in filter performance.

Auxiliary filter cleaning is sometimes used in the upper few inches of filter beds. This is conventionally referred to as surface wash and is accomplished by water jets just below the surface of the expanded bed during the backwash cycle. These jets enhance the scouring action in the bed by increasing the agitation.

An important feature for successful filtration and backwashing is the underdrain. This is the support structure for the bed. The underdrain provides an area for collection of the filtered water without clogging from either the filtered solids or the media grains. In addition, the underdrain prevents loss of the media with the water, and during the backwash cycle it provides even flow distribution over the bed. Failure to dissipate the velocity head during the filter or backwash cycle will result in bed upset and the need for major repairs.

Several standard approaches are used for filter underdrains. The simplest one consists of a parallel porous pipe imbedded under a layer of coarse gravel and manifolded to a header pipe for effluent removal. Other approaches to the underdrain system are known as the Leopold and Wheeler filter bottoms. Both of these incorporate false concrete bottoms with specific porosity configurations to provide drainage and velocity head dissipation.

Filter system operation may be manual or automatic. The filter backwash cycle may be on a timed basis, a pressure drop basis with a terminal value which triggers backwash, or a solids carryover basis from turbidity monitoring of the outlet stream. All of these schemes have been used successfully.

Application and Performance. Wastewater treatment plants often use granular bed filters for polishing after clarification, sedimentation, or other similar operations. Granular bed filtration thus has potential application to nearly all industrial plants. Chemical additives which enhance the upstream treatment equipment may or may not be compatible with or enhance the filtration process. Normal operation flow rates for various types of filters are as follows:

Slow Sand	2.04 - 5.30 l/sq m-hr
Rapid Sand	40.74 - 51.48 l/sq m-hr
High Rate Mixed Media	81.48 - 122.22 l/sq m-hr

Suspended solids are commonly removed from wastewater streams by filtering through a deep 0.3 to 0.9 m (1 to 3 feet) granular filter bed. The porous bed formed by the granular media can be designed to remove practically all suspended particles. Even colloidal suspensions (roughly 1 to 100 microns) are adsorbed on the surface of the media grains as they pass in close proximity in the narrow bed passages.

Properly operated filters following some preliminary treatment to reduce suspended solids below 200 mg/l should produce water with less than 10 mg/l TSS. For example, multimedia filters produced the effluent qualities shown in Table VII-9.

Advantages and Limitations. The principal advantages of granular bed filtration are its comparatively (to other filters) low initial and operating costs, reduced land requirements over other methods to achieve the same level of solids removal, and elimination of chemical additions to the discharge stream. However, the filter may require preliminary treatment if the solids level is high (over 100 mg/l). Operator training must be somewhat extensive due to the controls and periodic backwashing involved, and backwash must be stored and dewatered for economical disposal.

Operational Factors. Reliability: The recent improvements in filter technology have significantly improved filtration reliability. Control systems, improved designs, and good operating procedures have made filtration a highly reliable method of water treatment.

Maintainability: Deep bed filters may be operated with either manual or automatic backwash. In either case, they must be periodically inspected for media attrition, partial plugging, and leakage. Where backwashing is not used, collected solids must be removed by shoveling, and filter media must be at least partially replaced.

Solid Waste Aspects: Filter backwash is generally recycled within the wastewater treatment system, so that the solids ultimately appear in the clarifier sludge stream for subsequent dewatering. Alternatively, the backwash stream may be dewatered directly or, if there is no backwash, the collected solids may be disposed of in a suitable landfill. In either of these situations there is a solids disposal problem similar to that of clarifiers.

Demonstration Status. End-of-pipe filtration is demonstrated in the nonferrous metals manufacturing category in a total of 22 discharging plants: one primary aluminum plant; one primary electrolytic copper refinery; one secondary copper plant; one primary lead plant; seven secondary lead plants; three primary zinc plants; three secondary silver plants; one primary columbium-tantalum plant; three primary tungsten plants; and three acid plants. Long-term paired data from a primary zinc plant were considered in establishing treatment performance concentrations for lime, settle and filtration technology (see L,S&F Performance, p.249).

Pressure Filtration

Pressure filtration works by pumping the liquid through a filter material which is impenetrable to the solid phase. The positive pressure exerted by the feed pumps or other mechanical means provides the pressure differential which is the principal driving force. Figure VII-8 represents the operation of one type of pressure filter.

A typical pressure filtration unit consists of a number of plates or trays which are held rigidly in a frame to ensure alignment and which are pressed together between a fixed end and a traveling end. On the surface of each plate is mounted a filter made of cloth or a synthetic fiber. The feed stream is pumped into the unit and passes through holes in the trays along the length of the press until the cavities or chambers between the trays are completely filled. The solids are then entrapped, and a cake begins to form on the surface of the filter material. The water passes through the fibers, and the solids are retained.

At the bottom of the trays are drainage ports. The filtrate is collected and discharged to a common drain. As the filter medium becomes coated with sludge, the flow of filtrate through the filter drops sharply, indicating that the capacity of the filter has been exhausted. The unit must then be cleaned of the sludge. After the cleaning or replacement of the filter media, the unit is again ready for operation.

Application and Performance. Pressure filtration is used in nonferrous metals manufacturing for sludge dewatering and also for direct removal of precipitated and other suspended solids from wastewater.

Because dewatering is such a common operation in treatment systems, pressure filtration is a technique which can be found in many industries concerned with removing solids from their waste stream.

In a typical pressure filter, chemically preconditioned sludge detained in the unit for one to three hours under pressures varying from 5 to 13 atmospheres exhibited a final dry solids content between 25 and 50 percent.

Advantages and Limitations. The pressures which may be applied to a sludge for removal of water by filter presses that are currently available range from 5 to 13 atmospheres. As a result, pressure filtration may reduce the amount of chemical pretreatment required for sludge dewatering. Sludge retained in the form of the filter cake has a higher percentage of solids than that from a centrifuge or vacuum filter. Thus, it can be easily accommodated by materials handling systems.

As a primary solids removal technique, pressure filtration requires less space than clarification and is well suited to streams with high solids loadings. The sludge produced may be disposed of without further dewatering. The amount of sludge is increased by the use of filter precoat materials (usually diatomaceous earth). Also, cloth pressure filters often do not achieve as high a degree of effluent clarification as clarifiers or granular media filters.

Two disadvantages associated with pressure filtration in the past have been the short life of the filter cloths and lack of automation. New synthetic fibers have largely offset the first of these problems. The second problem has been reduced because of the current availability of units with automatic feeding and pressing cycles.

For larger operations, the relatively high space requirements, as compared to those of a centrifuge, could be prohibitive in some situations.

Operational Factors. Reliability: With proper pretreatment, design, and control, pressure filtration is a highly dependable system.

Maintainability: Maintenance consists of periodic cleaning or replacement of the filter media, drainage grids, drainage piping, filter pans, and other parts of the system. If the removal of the sludge cake is not automated, additional time is required for this operation.

Solid Waste Aspects: Because it is generally drier than other types of sludges, the filter sludge cake can be handled with relative ease. The accumulated sludge may be disposed by any of the accepted procedures depending on its chemical composition. The levels of toxic metals present in sludge from treating nonferrous metals manufacturing wastewater necessitate proper disposal.

Demonstration Status. Pressure filtration is a commonly used technology in many commercial applications. Several nonferrous metals manufacturing plants use pressure filtration for sludge dewatering.

Settling

Settling is a process which removes solid particles from a liquid matrix by gravitational force. This is done by reducing the velocity of the feed stream in a large volume tank or lagoon so that gravitational settling can occur. Figure VII-9 shows two typical settling devices.

Settling is often preceded by chemical precipitation, which converts dissolved pollutants to solid form, and by coagulation, which enhances settling by coagulating suspended precipitates into larger, faster settling particles.

If no chemical pretreatment is used, the wastewater is fed into a tank or lagoon where it loses velocity and the suspended solids are allowed to settle out. Long retention times are generally required. Accumulated sludge can be collected either periodically or continuously and either manually or mechanically. Simple settling, however, may require excessively large catchments, and long retention times (days as compared with hours) to achieve high removal efficiencies. Because of this, addition of settling aids such as alum or polymeric flocculants is often economically attractive.

In practice, chemical precipitation often precedes settling, and inorganic coagulants or polyelectrolytic flocculants are usually added as well. Common coagulants include sodium sulfate, sodium aluminate, ferrous or ferric sulfate, and ferric chloride. Organic polyelectrolytes vary in structure, but all usually form larger floc particles than coagulants used alone.

Following this pretreatment, the wastewater can be fed into a holding tank or lagoon for settling, but is more often piped into a clarifier for the same purpose. A clarifier reduces space requirements, reduces retention time, and increases solids removal efficiency. Conventional clarifiers generally consist of a circular or rectangular tank with a mechanical sludge collecting device or with a sloping funnel-shaped bottom designed for sludge collection. In advanced settling devices, inclined plates, slanted tubes, or a lamellar network may be included within the clarifier tank in order to increase the effective settling area, increasing capacity. A fraction of the sludge stream is often recirculated to the inlet, promoting formation of a denser sludge.

Application and Performance. Settling and clarification are used in the nonferrous metals manufacturing category to remove precipitated metals. Settling can be used to remove most suspended solids in a particular waste stream; thus it is used extensively by many different industrial waste treatment facilities. Because most metal ion pollutants are readily converted to solid metal hydroxide precipitates, settling is of particular use in those industries associated with metal production, metal finishing, metal working, and any other industry with high concentrations of metal ions in their wastewaters. In addition to toxic metals, suitably precipitated materials effectively removed by settling include aluminum, iron, and fluoride.

A properly operated settling system can efficiently remove suspended solids, precipitated metal hydroxides, and other impurities from wastewater. The performance of the process depends on a variety of factors, including the density and particle size of the solids, the effective charge on the suspended particles, and the types of chemicals used in pretreatment. The site of flocculant or coagulant addition also may significantly influence the effectiveness of clarification. If the flocculant is subjected to too much mixing before entering the clarifier, the complexes may be sheared and the settling effectiveness diminished. At the same time, the flocculant must have sufficient mixing and reaction time in order for effective set-up and settling to occur. Plant personnel have observed that the line or trough leading into the clarifier is often the most efficient site for flocculant addition. The performance of simple settling is a function of the retention time, particle size and density, and the surface area of the basin.

The data displayed in Table VII-10 indicate suspended solids removal efficiencies in settling systems. The mean effluent TSS concentration obtained by the plants shown in Table VII-10 is 10.1 mg/l. Influent concentrations averaged 838 mg/l. The maximum effluent TSS value reported is 23 mg/l. These plants all use alkaline pH adjustment to precipitate metal hydroxides, and most add a coagulant or flocculant prior to settling.

Advantages and Limitations. The major advantage of simple settling is its simplicity as demonstrated by the gravitational settling of solid particular waste in a holding tank or lagoon. The major problem with simple settling is the long retention time necessary to achieve an acceptable effluent, especially if the specific gravity of the suspended matter is close to that of water. Some materials cannot be effectively removed by simple settling alone.

Settling performed in a clarifier is effective in removing slow-settling suspended matter in a shorter time and in less space than a simple settling system. Also, effluent quality is often better from a clarifier. The cost of installing and maintaining a clarifier, however, is substantially greater than the costs associated with simple settling.

Inclined plate, slant tube, and lamellar settlers have even higher removal efficiencies than conventional clarifiers, and greater capacities per unit area are possible. Installed costs for these advanced clarification systems are claimed to be one half the cost of conventional systems of similar capacity.

Operational Factors. Reliability: Settling can be a highly reliable technology for removing suspended solids. Sufficient retention time and regular sludge removal are important factors affecting the reliability of all settling systems. Proper control of pH adjustment, chemical precipitation, and coagulant or flocculant addition are other factors affecting settling efficiencies in systems (frequently clarifiers) where these methods are used.

Those advanced settlers using slanted tubes, inclined plates, or a lamellar network may require prescreening of the waste in order to eliminate any fibrous materials which could potentially clog the system. Some installations are especially vulnerable to shock loadings, as by storm water runoff, but proper system design will prevent this.

Maintainability: When clarifiers or other advanced settling devices are used, the associated system utilized for chemical pretreatment and sludge dragout must be maintained on a regular basis. Routine maintenance of mechanical parts is also necessary. Lagoons require little maintenance other than periodic sludge removal.

Demonstration Status. Settling represents the typical method of solids removal and is used extensively in industrial waste treatment. At least 60 nonferrous metals manufacturing plants use settling, usually in conjunction with chemical precipitation. The advanced clarifiers are just beginning to appear in significant numbers in commercial applications. As an example, a lamellar inclined-tube clarifier is used by one secondary copper smelter.

Skimming

Pollutants with a specific gravity less than water will often float unassisted to the surface of the wastewater. Skimming removes these floating wastes. Skimming normally takes place in a tank designed to allow the floating material to rise and remain on the surface, while the liquid flows to an outlet located below the floating layer. Skimming devices are therefore suited to the removal of non-emulsified oils from raw waste streams. Common skimming mechanisms include the rotating drum type, which picks up oil from the surface of the water as it rotates. A doctor blade scrapes oil from the drum and collects it in a trough for disposal or reuse. The water portion is allowed to flow under the rotating drum. Occasionally, an underflow baffle is installed after the drum; this has the advantage of retaining any floating oil which escapes the drum skimmer. The belt type skimmer is pulled vertically through the water, collecting oil which is scraped off from the surface and collected in a drum. Gravity separators (Figure VII-10), such as the API type, utilize overflow and underflow baffles to skim a floating oil layer from the surface of the wastewater. An overflow-underflow baffle allows a small amount of wastewater (the oil portion) to flow over into a trough for disposition or reuse while the majority of the water flows underneath the baffle. This is followed by an overflow baffle, which is set at a height relative to the first baffle such that only the oil bearing portion will flow over the first baffle during normal plant operation. A diffusion device, such as a vertical slot baffle, aids in creating a uniform flow through the system and increasing oil removal efficiency.

Application and Performance. Skimming is applicable to any waste stream containing pollutants which float to the surface. It is commonly used to remove free oil, grease, and soaps. Skimming is often used in conjunction with air flotation or clarification in order to increase its effectiveness.

The removal efficiency of a skimmer is partly a function of the retention time of the water in the tank. Larger, more buoyant particles require less retention time than smaller particles. Thus, the efficiency also depends on the composition of the waste stream. The retention time required to allow phase separation and subsequent skimming varies from 1 to 15 minutes, depending on the wastewater characteristics.

API or other gravity-type separators are more effective where the amount of surface oil flowing through the system is continuous and substantial. Drum and belt type skimmers are applicable to waste streams which evidence smaller amounts of floating oil and where surges of floating oil are not a problem. Using an API separator system in conjunction with a drum type skimmer would be a very effective method of removing floating contaminants from non-emulsified oily waste streams. Sampling data shown in Table VII-11 illustrate the capabilities of the technology with both extremely high and moderate oil influent levels.

This data is intended to be illustrative of the very high level of oil and grease removals attainable in a simple two-stage oil removal system. Based on the performance of installations in a variety of manufacturing plants, and on permit requirements that are constantly achieved, it is determined that effluent oil levels may be reliably reduced below 10 mg/l with moderate influent concentrations. Very high concentrations of oil such as the 22 percent shown in Table VII-11 may require two-step treatment to achieve this level. However, these concentrations are not typically found in nonferrous wastewater.

Advantages and Limitations. Skimming as a pretreatment is effective in removing naturally floating waste material. It also improves the performance of subsequent downstream treatments.

Many pollutants, particularly dispersed or emulsified oil, will not float "naturally" but require additional treatments. Therefore, skimming alone may not remove all the pollutants capable of being removed by air flotation or other more sophisticated technologies.

Operational Factors. Reliability: Because of its simplicity, skimming is a very reliable technique.

Maintainability: The skimming mechanism requires periodic lubrication, adjustment, and replacement of worn parts.

Solid Waste Aspects: The collected layer of debris must be disposed of by contractor removal, landfill, or incineration. Because relatively large quantities of water are present in the collected wastes, incineration is not always a viable disposal method.

Demonstration Status. Skimming is a common operation utilized extensively by industrial waste treatment systems.

MAJOR TECHNOLOGY EFFECTIVENESS

The performance of individual treatment technologies was presented above. Performance of operating systems is discussed here. Five different systems are considered: L&S (hydroxide precipitation and sedimentation or lime and settle), LS&F (hydroxide precipitation, sedimentation, and filtration or lime, settle, and filter), cyanide precipitation, ammonia steam stripping, and activated carbon adsorption. Subsequently, an analysis of effectiveness of such systems is made to develop one-day maximum and ten-day and thirty-day average concentration levels to be used in regulating pollutants. Evaluation of the L&S and the LS&F systems is carried out on the assumption that cyanide precipitation and oil skimming are installed and operating properly where appropriate.

L&S Performance - Combined Metals Data Base

Chemical analysis data were collected of raw waste (treatment influent) and treated waste (treatment effluent) from 55 plants

(126 data days) sampled by EPA (or its contractor) using EPA sampling and chemical analysis protocols. These data are the data base for determining the effectiveness of L&S technology. Each of these plants belongs to at least one of the following industry categories: aluminum forming, battery manufacturing, coil coating, copper forming, electroplating and porcelain enameling. All of the plants employ pH adjustment and hydroxide precipitation using lime or caustic, followed by settling (tank, lagoon or clarifier) for solids removal. Most also add a coagulant or flocculant prior to solids removal.

Analytical data from nonferrous metals manufacturing treatment systems which include paired raw waste influent treatment and treated effluent are limited to six nonferrous metals manufacturing plants with properly operated lime precipitation and sedimentation systems.

The treated data from the six nonferrous plants were compared to the achievable concentrations derived using the combined data base. These data supported the combined data base concentrations. These data and the analysis performed using the data are in the administrative record supporting this rulemaking. Additionally, EPA examined the homogeneity among nonferrous subcategories, as well as across nonferrous subcategories and the combined metals data base. Homogeneity is the absence of statistically discernable differences among mean pollutant concentrations observed in a set of data. The purpose of these analyses was to check the Agency's engineering judgement that the untreated wastewater characteristics observed in the nonferrous category were similar to those observed in the combined metals data. Establishment of similarity of raw wastes through a statistical assessment provides further support to EPA's assumption that lime and settle treatment reduces the toxic metal pollutant concentrations in untreated nonferrous wastewater to concentrations achieved by the same technology applied to the wastewater from the categories in the combined metals data base. In general, the results of the analysis showed that the nonferrous subcategories are homogeneous with respect to mean pollutant concentrations across subcategories. Comparison of the untreated nonferrous metals manufacturing data combined across subcategories and the combined metals data also showed good agreement.

The homogeneity observed among the nonferrous untreated data and the combined metals data supports the hypothesis of similar untreated wastewater characteristics and suggests that lime and settle treatment would reduce the concentrations of toxic metal pollutants inthe nonferrous metals manufacturing category to concentrations comparable to those achievable by lime and settle treatment of wastewater from the categories included in the combined metals data base. After considering these points and the fact that the combined data base consisted of more plants and paired data points, the Agency decided to use the combined metals data base.

Properly operated hydroxide precipitation and sedimentation will result in effluent concentrations that are directly related to pollutant solubilities. Since the nonferrous metals manufacturing raw wastewater matrix contains the same toxic pollutants in the same order of magnitude as the combined metals data base raw wastewater and the technology is solubility-based, the mean treatment process effluent and variability will be quite similar. In addition, no interfering properties (such as chelating agents) exist in nonferrous metals manufacturing wastewater that would interfere with metal precipitation and so prevent attaining concentrations calculated from the combined metals data base.

It should be noted, however, that statistical analyses indicate that the raw wastewater matrix in nonferrous metals manufacturing contains higher concentrations of lead and cadmium than the raw wastewater of plants used for the combined metals data base. Because the precipitation (and ultimate removal by sedimentation) of these metals is directly related to their solubility, EPA believes that the differences in raw waste concentrations, while statistically significant, are not large enough to alter the achievable concentrations following treatment.

An analysis of this combined data base was presented in the development documents for the proposed regulations for coil coating and porcelain enameling (January, 1981). In response to the proposal, some commentors claimed that it was inappropriate to use data from some categories for regulation of other categories. In response to these comments, the Agency reanalyzed the data. An analysis of variance was applied to the data for the 126 days of sampling to test the hypothesis of homogeneous plant mean raw and treated effluent levels across categories by pollutant. This analysis is described in the report, "A Statistical Analysis of the Combined Metals Industries Effluent Data" which is in the administrative record supporting this rulemaking. The main conclusion drawn from the analysis of variance is that, with the exception of electroplating, the categories are generally homogeneous with regard to mean pollutant concentrations in both raw and treated effluent. That is, when data from electroplating facilities are included in the analysis, the hypothesis of homogeneity across categories is rejected. When the electroplating data are removed from the analysis, hypothesis of homogeneity across categories is confirmed. On the basis of this analysis, the electroplating data were removed from the data base used to determine limitations. Where pollutants were present in higher concentrations in raw wastewater from some categories (such as copper in copper forming and lead in lead battery manufacturing) were expected and were accommodated in developing limitations by using the larger values obtained from the marginally different category to characterize the entire data set.

The statistical analysis provides support for the technical engineering judgement that electroplating wastewaters are different from most metal processing wastewater. These differences may be further explained by differences in the constituents and relative concentrations of pollutants in the raw wastewaters. Therefore, the wastewater data derived from plants that only electroplate are not used in developing limitations for the nonferrous metals manufacturing category.

After removing the electroplating data, data from 21 plants and 52 days of sampling remained.

Prior to performing the homogeneity analysis, certain data were deleted from the data base. The following criteria were used in making these deletions:

- Plants where malfunctioning processes or treatment systems at time of sampling were identified.
- Data days where pH was less than 7.0 or TSS was greater than 50 mg/l. (This is a prima facie indication of poor operation).

For the purpose of developing treatment effectiveness, following homogeneity, additional deletions were made. These deletions were made, almost exclusively, in cases where effluent data points were associated with raw waste values too low to assure actual pollutant removal (i.e., less than 0.1 mg/l of pollutant in raw waste). A few data points were also eliminated following the homogeneity analysis where malfunctions not previously identified were recognized.

Collectively, these selection criteria ensure that the data are from properly operating lime and settle treatment facilities. The remaining data are displayed graphically in Figures VII-11 to VII-19. This common or combined metals data base provides a more sound and usable basis for estimating treatment effectiveness and statistical variability of lime and settle technology than the available data from any one category.

One-Day Effluent Values

The basic assumption underlying the determination of treatment effectiveness is that the data for a particular pollutant are lognormally distributed by plant. The lognormal distribution has been found to provide a satisfactory fit to plant effluent data in a number of effluent guidelines categories. In the case of the combined metal categories data base, there are too few data from any one plant to verify formally the lognormal assumption. Thus, we assumed measurements of each pollutant from a particular plant, denoted by X, follow a lognormal distribution with a log mean μ and log variance σ^2. The mean, variance, and 99th percentile of X are then:

$$\text{mean of } X = E(X) = \exp(\mu + \sigma^2/2)$$

$$\text{variance of } X = V(X) = \exp(2\mu + \sigma^2)\ [\exp(\sigma^2) - 1]$$

$$\text{99th percentile} = X_{.99} = \exp(\mu + 2.33\sigma)$$

where exp is e, the base of the natural logarithm. The term lognormal is used because the logarithm of X has a normal distribution with mean μ and variance σ^2. Using the basic assumption of lognormality, the actual treatment effectiveness was determined using a lognormal distribution that, in a sense, approximates the distribution of an average of the plants in the data base, i.e., an "average plant" distribution. The notion of an "average plant" distribution is not a strict statistical concept but is used here to determine limits that would represent the performance capability of an average of the plants in the data base.

This "average plant" distribution for a particular pollutant was developed as follows: the log mean was determined by taking the average of all the observations for the pollutant across plants. The log variance was determined by the pooled within-plant variance. This is the weighted average of the plant variances. Thus, the log mean represents the average of all the data for the pollutant and the log variance represents the average of the plant log variances or average plant variability for the pollutant.

The one-day effluent values were determined as follows:

Let X_{ij} = the jth observation on a particular pollutant at plant i, where

$i = 1, \ldots, I$
$j = 1, \ldots, J_i$
I = total number of plants
J_i = number of observations at plant i.

Then $Y_{ij} = \ln X_{ij}$

where ln means the natural logarithm.

Then $\bar{y}$ = log mean over all plants

$$= \sum_{i=1}^{I} \sum_{j=1}^{J_i} y_{ij}/n$$

where n = total number of observations

$$= \sum_{i=1}^{I} J_i$$

and V(y) = pooled log variance

$$= \frac{\sum_{i=1}^{I} (J_i-1)S_i^2}{= \sum_{i=1}^{I} (J_i-1)}$$

where S_i^2 = log variance at plant i

$$= \sum_{j=1}^{J_i} (\bar{y}_{ij}-y_i)^2/(J_i-1)$$

$\bar{y}_i$ = log mean at plant i.

Thus, y and V(y) are the log mean and log variance, respectively, of the lognormal distribution used to determine the treatment effectiveness. The estimated mean and 99th percentile of this distribution form the basis for the long-term average and daily maximum effluent limitations, respectively. The estimates are

$$\text{mean} = \hat{E}(X) = \exp(\bar{y})\psi n(0.5V(y))$$

$$\text{99th percentile} = \hat{X}_{.99} = \exp[\bar{y} + 2.33\sqrt{V(y)}]$$

where ψ(.) is a Bessel function and exp is e, the base of the natural logarithms (see Aitchison, J. and J. A. C. Brown, The Lognormal Distribution, Cambridge University Press, 1963). In cases where zeros were present in the data, a generalized form of the lognormal distribution, known as the delta distribution, was used (see Aitchison and Brown, op. cit., Chapter 9).

For certain pollutants, this approach was modified slightly to accommodate situations in which a category or categories stood out as being marginally different from the others. For instance, after excluding the electroplating data and other data that did not reflect pollutant removal or proper treatment, the effluent copper data from the copper forming plants were statistically significantly greater than the copper data from the other plants. Thus, copper effluent values shown in Table VII-12 are based only on the copper effluent data from the copper forming plants. That is, the log mean for copper is the mean of the logs of all copper values from the copper forming plants only and the log variance is the pooled log variance of the copper forming plant data only. In the case of cadmium, after excluding the electroplating data and data that did not reflect removal or proper treatment, there were insufficient data to estimate the log variance for cadmium. The variance used to determine the values shown in Table VII-12 for cadmium was estimated by pooling the within-plant variances for all the other metals. Thus, the cadmium variability is the average of the plant variability averaged over all the other metals. The log mean for cadmium is the mean of the logs of the cadmium observations only. A complete discussion of the data and calculations for all the metals is contained in the administrative record for this rulemaking.

Average Effluent Values

Average effluent values that form the basis for the monthly limitations were developed in a manner consistent with the method used to develop one-day treatment effectiveness in that the log-normal distribution used for the one-day effluent values was also used as the basis for the average values. That is, we assume a number of consecutive measurements are drawn from the distribution of daily measurements.

In response to the proposed coil coating and porcelain enameling regulations, the Agency received comments pointing out that permits usually required less than 30 samples to be taken during a month while the monthly average used as the basis for permits and pretreatment requirements is based on the average of 30 samples.

In applying the treatment effectiveness values to regulations, the Agency has considered the comments, examined the sampling frequency required by many permits, and considered the change in values of averages depending on the number of consecutive sampling days in the averages. The frequency of sampling required in most permits is about 10 samples per month or slightly greater than twice weekly. The 99th percentiles of the distribution of averages of 10 consecutive sampling days are not substantially different from the 99th percentile of the distribution's 30-day average. (Compared to the one-day maximum, the 10-day average is about 80 percent of the difference between one-day and 30-day values). Hence, the 10-day average provides a reasonable basis for a monthly average and is typical of the sampling frequency required by existing permits.

The approach used for the 10 measurements values was used previously for the electroplating category (see "Development Document for Existing Sources Pretreatment Standards for the Electroplating Point Source Category," EPA 440/1-79/003, U.S. Environmental Protection Agency, Washington, D.C., August, 1979). That is, the distribution of the average of 10 samples from a lognormal was approximated by another lognormal distribution. Although the approximation is not precise theoretically, there is empirical evidence based on effluent data from a number of categories that the lognormal is an adequate approximation for the distribution of small samples. In the course of previous work the approximation was verified in a computer simulation study. The average values were developed assuming independence of the observations although no particular sampling scheme was assumed.

The monthly average is to be achieved in all permits and pretreatment standards regardless of the number of samples required to be analyzed and averaged by the permitting or pretreatment authority.

Ten-Sample Average:

The formulas for the 10-sample limitations were derived on the basis of simple relationships between the mean and variance of the distributions of the daily pollutant measurements and the average of 10 measurements. It is assumed that the daily concentration measurements for a particular pollutant, denoted by X, follow a lognormal distribution with log mean and log variance denoted by μ and σ^2, respectively. Let X_{10} denote the mean of 10 consecutive measurements. The following relationships then hold assuming the daily measurements are independent:

$$\text{mean of } \bar{X}_{10} = E(\bar{X}_{10}) = E(X)$$

$$\text{variance of } \bar{X}_{10} = V(\bar{X}_{10}) = V(X) \div 10.$$

where E(X) and V(X) are the mean and variance of X, respectively, defined above. It is then assumed that X_{10} follows a lognormal distribution with log mean μ_{10} and log standard deviation σ^2_{10}. The mean and variance of X_{10} are then

$$\bar{E}(X_{10}) = \exp(\mu_{10} + 0.5\sigma^2_{10})$$

$$V(X_{10}) = \exp(2\mu_{10} + \sigma^2_{10})[\exp(\sigma^2_{10}) - 1]$$

Now, μ_{10} and σ^2_{10} can be derived in terms of μ and σ^2 as

$$\mu_{10} = \mu + \sigma^2/2 - 0.5 \ln[1 + (\exp(\sigma^2) - 1)/N]$$

$$\sigma^2_{10} = \ln[1 + (\exp(\sigma^2) - 1)/N].$$

Therefore, μ_{10} and σ^2_{10} can be estimated using the above relationships and the estimates of μ and σ^2 obtained for the underlying lognormal distribution. The 10-sample limitation value was determined by the estimate of the approximate 99th percentile of the distribution of the 10-sample average given by

$$\hat{X}_{10}(.99) = \exp(\hat{\mu}_{10} + 2.33\ \hat{\sigma}_{10})$$

where $\hat{\mu}_{10}$ and $\hat{\sigma}_{10}$ are the estimates of μ_{10} and σ_{10}, respectively.

30-Sample Average:

The average values based on 30 measurements are determined on the basis of a statistical result known as the Central Limit Theorem. This Theorem states that, under general and nonrestrictive assumptions, the distribution of a sum of a number of random variables, say n, is approximated by the normal distribution. The approximation improves as the number of variables, n, increases. The Theorem is quite general in that no particular distributional form is assumed for the distribution of the individual variables. In most applications (as in approximating the distribution of 30-day averages) the Theorem is used to approximate the distribution of the average of n observations of a random variable. The result makes it possible to compute approximate probability statements about the average in a wide range of cases. For instance, it is possible to compute a value below which a specified percentage (e.g., 99 percent) of the averages of n observations are likely to fall. Most textbooks state that 25 or 30 observations are sufficient for the approximation to be valid. In applying the Theorem to the determination of 30-day average effluent values, we approximate the distribution of the average of 30 observations drawn from the distribution of daily measurements and use the estimated 99th percentile of this distribution. The monthly limitations based on 10 consecutive measurements were determined using the lognormal approximation described above because 10 measurements were, in this case, considered too small a number for use of the Central Limit Theorem.

30-Sample Average Calculation

The formulas for the 30-sample average were based on an application of the Central Limit Theorem. According to the Theorem, the average of 30 observations drawn from the distribution of daily measurements, denoted by X_{30}, is approximately normally distributed. The mean and variance of X_{30} are

$$\text{mean of } \bar{X}_{30} = E(\bar{X}_{30}) = E(X)$$

$$\text{variance of } \bar{X}_{30} = V(\bar{X}_{30}) = V(X) \div 30.$$

The 30-sample average value was determined by the estimate of the approximate 99th percentile of the distribution of the 30-sample average given by

$$\hat{X}_{30}(.99) = \hat{E}(X) + 2.33\sqrt{\hat{V}(X) \div 30}$$

where $\hat{E}(X) = \exp(\bar{y})\psi n(0.5V(y))$

and $\hat{V}(X) = \exp(2\bar{y})[\psi n(2V(y)) - \psi n\left(\left(\frac{n-2}{n-1}\right) V(y)\right)].$

The formulas for E(X) and V(X) are estimates of E(X) and V(X), respectively given in Aitchison, J. and J. A. C. Brown, The Lognormal Distribution, Cambridge University Press, 1963, page 45.

Additional Pollutants

Nonferrous metals manufacturing wastewaters contain several other toxic metals treatable by lime and settle technology but not part of the combined metals data base. Paired performance data for these parameters are not readily available, so data available to the Agency in other categories have been selectively used to determine the long-term average performance of lime and settle technology for each pollutant. These data indicate that the concentrations shown in Table VII-13 are reliably attainable by nonferrous plants with well-operated hydroxide precipitation and settling. The precipitation of silver appears to be accomplished by alkaline chloride precipitation and adequate chloride ions must be available for this reaction to occur.

In establishing which data were suitable for use in Table VII-13 two factors were heavily weighed: (1) the nature of the wastewater; and (2) the range of pollutants or pollutant matrix in the raw wastewater. These data have been selected from processes that generate dissolved metals in the wastewater and which are generally free from complexing agents. The pollutant matrix was evaluated by comparing the concentrations of pollutants found in the raw wastewaters with the range of pollutants in the raw wastewaters of the combined metals data set. These data are displayed in Tables VII-14 and VII-15 and indicate that there is sufficient similarity in the raw wastes to assume a logical transferability of the treated pollutant concentrations to the combined metals data base. The available data on these added pollutants do not allow homogeneity analysis as was performed on the combined metals data base. The data source for each added pollutant is discussed separately.

Antimony (Sb) - The achievable performance for antimony is based on data from a battery manufacturing and secondary lead plant. Both EPA sampling data and recent permit data (1978 to 1982) confirm the achievability of 0.7 mg/l in the battery manufacturing wastewater matrix included in the combined data set.

Arsenic (As) - The achievable performance of 0.5 mg/l for arsenic is based on permit data from two nonferrous metals manufacturing plants. The untreated wastewater matrix shown in Table VII-15 is comparable with the combined data set matrix based on the maximum concentrations observed.

Beryllium (Be) - The treatability of beryllium is from the nonferrous metals manufacturing industry. The 0.3 mg/l performance is achieved at a beryllium plant with the comparable untreated wastewater matrix shown in Table VII-15.

Mercury (Hg) - The 0.06 mg/l treatability of mercury is based on data from four battery plants. The untreated wastewater matrix at these plants was considered in the combined metals data set.

Selenium (Se) - The 0.30 mg/l treatability of selenium is based on recent permit data from one of the nonferrous metals manufacturing plants also used for arsenic performance. The untreated wastewater matrix for this plant is shown in Table VII-15.

Silver (Ag) - The treatability of silver is based on a 0.1 mg/l treatability estimate from the inorganic chemicals industry. Additional data supporting a treatability as stringent or more stringent than 0.1 mg/l are also available from seven nonferrous metals manufacturing plants. The untreated wastewater matrix for these plants is comparable to the combined metals data set plants and is summarized in Table VII-15.

Thallium (Th) - The 0.50 mg/l treatability for thallium is transferred from the inorganic chemicals industry. Although no untreated wastewater data are available to verify comparability with the combined metals data set plants, no other sources of data for thallium treatability could be identified.

Aluminum (Al) - The 1.11 mg/l treatability of aluminum is based on the mean performance of one aluminum forming plant and one coil coating plant. Both of the plants are from categories considered in the combined metals data set, assuring untreated wastewater matrix comparability.

Fluoride (F) - The 14.5 mg/l treatability of fluoride is based on the mean performance of an electronics and electrical component manufacturing plant. The untreated wastewater matrix for this plant shown in Table VII-15 is comparable to the combined metals data set.

The mean concentrations from nonferrous plants with well operated lime precipitation and sedimentation that the Agency sampled indicates that the plants are meeting the limits for six pollutants (antimony, arsenic, aluminum, selenium, silver, and fluoride). EPA believes that the proposed limitations for arsenic and selenium are achievable because they are based on permit data from nonferrous metal plants including one of the six plants with treatment sampled by EPA.

LS&F Performance

Tables VII-16 and VII-17 show long-term data from two plants which have well operated precipitation-settling treatment followed by filtration. These data were used to provide treatment effectiveness numbers for lime, settle and filtration performance for the toxic metals chromium, copper, nickel, zinc, and iron. The wastewaters from both plants contain pollutants from metals processing and finishing operations (multi-category). Both plants reduce hexavalent chromium before neutralizing and precipitating metals with lime. A clarifier is used to remove much of the solids load and a filter is used to "polish" or complete removal of suspended solids. Plant A uses pressure filtration, while Plant B uses a rapid sand filter.

Raw waste data was collected only occasionally at each facility and is presented as an indication of the nature of the wastewater treated. Data from Plant A was received as a statistical summary and is presented as received. Raw laboratory data was collected at Plant B and reviewed for spurious points and discrepancies. The method of treating the data base is discussed below under lime, settle, and filter treatment effectiveness.

Table VII-18 shows long-term data for zinc and cadmium removal at Plant C, a primary zinc plant, which operates a LS&F system. This data represents approximately four months (103 data days) and has been arranged similarly to the data collected from plants A and B for comparison and use. Lime, settle and filtration treatment values for cadmium are based on this data.

It should be noted that the iron content of the raw waste of plants A and B is high while that for Plant C is low. This results, for plants A and B, in co-precipitation of toxic metals with iron. Precipitation using high-calcium lime for pH control yields the results shown in Table VII-18. Plant operating personnel indicate that this chemical treatment combination (sometimes with polymer assisted coagulation) generally produces better and more consistent metals removal than other combinations of sacrificial metal ions and alkalis.

The LS&F performance data presented here are based on systems that provide polishing filtration after effective L&S treatment. EPA believes that the use of polishing filtration data from porcelain enameling plants is justified because porcelain enameling was included in the combined metals data base. Since it was determined that lime precipitation and sedimentation will produce identical results on both nonferrous metals manufacturing and porcelain enameling wastewater, it is reasonable to assume that polishing filters treating these identical intermediate waste streams will produce an identical final effluent. Although the one nonferrous plant sampled only supplied data for cadmium, zinc, and TSS, its attainment of the limitations calculated from the extensive porcelain enameling data suggests the ability to attain the other limitations because of the nonpreferential nature of toxic metal removal by filters.

Analysis of Treatment System Effectiveness

Data are presented in Table VII-12 showing the mean, one day, 10-day, and 30-day values for nine pollutants examined in the L&S metals data base. The mean variability factor for each of eight pollutants (excluding cadmium because of the small number of data points) was determined and is used to estimate one day, 10-day, and 30-day values. (The variability factor is the ratio of the value of concern to the mean: the average variability factors are: one day maximum - 4.100; ten-day average - 1.821; and 30-day average - 1.618.) For values not calculated from the common data base as previously discussed, the mean values for pollutants shown in Table VII-13 were multiplied by the mean variability factors of the eight combined data base pollutants to derive the value to obtain the one, 10- and 30-day values. These are tabulated in Table VII-19.

LS&F technology data are presented in Tables VII-16 and VII-17. These data represent two operating plants (A and B) in which the technology has been installed and operated for some years. Plant A data was received as a statistical summary and is presented without change. Plant B data was received as raw laboratory analysis data. Discussions with plant personnel indicated that operating experiments and changes in materials and reagents and occasional operating errors had occurred during the data collection period. No specific information was available on those variables. The Plant B data were analyzed to sort out high values probably caused by methodological factors from random statistical variability, or data noise. For each of the four pollutants (chromium, nickel, zinc, and iron), the mean and standard deviation (sigma) were calculated for the entire data set. A data day was removed from the complete data set when any individual pollutant concentration for that day exceeded the sum of the mean plus three sigma for that pollutant. Fifty-one data days (from a total of about 1,300) were eliminated by this method.

Another approach was also used as a check on the above method of eliminating certain high values. The minimum values of raw wastewater concentrations from Plant B for the same four pollutants were compared to the total set of values for the corresponding pollutants. When pollutant concentration exceeded the minimum value selected from raw wastewater, concentrations for that pollutant were discarded. Forty-five days of data were eliminated by this procedure. Forty-three common days of data were eliminated by both procedures. Since common engineering practice (mean plus 3 sigma) and logic (treated waste should be less than raw waste) seem to coincide, the data base with the 51 spurious data days eliminated is the basis for all further analysis. Range, mean, standard deviation and mean plus two standard deviations are shown in Tables VII-16 and VII-17 for Cr, Cu, Ni, Zn, and Fe.

The Plant B data were separated into 1979, 1978, and total data base (six years) segments. Combined with the statistical analysis from Plant A for 1978 and 1979, this in effect created five data sets, in which there is some overlap between the individual years and total data sets from Plant B. By comparing these five parts it is apparent that they are quite similar and all appear to be from the same family of numbers. The largest mean found among the five data sets for each pollutant was selected as the long-term mean for LS&F technology and is used as the LS&F mean in Table VII-19.

Plant C data were used as a basis for cadmium removal performance and as a check on the zinc values derived from plants A and B. The cadmium data are displayed in Table VII-18 and are incorporated into Table VII-19 for LS&F. The zinc data were analyzed for compliance with the one-day and 30-day values in Table VII-19; no zinc value of the 103 data points exceeded the one-day zinc value of 1.02 mg/l. The 103 data points were separated into blocks of 30 points and averaged. Each of the three full 30-day averages was less than the Table VII-19 value of 0.31 mg/l. Additionally, the Plant C raw wastewater pollutant concentrations (Table VII-18) are well within the range of raw wastewater concentrations of the combined metals data base (Table VII-14), further supporting the conclusion that Plant C wastewater data are compatible with similar data from plants A and B.

Concentration values for regulatory use are displayed in Table VII-19. Mean one-day, ten-day, and 30-day values for L&S for nine pollutants were taken from Table VII-12; the remaining L&S values were developed using the mean values in Table VII-13 and the mean variability factors discussed above. (It is appropriate to use these variability factors for the additional pollutants, since the combined data base is a detailed data set for this technology, and the additional pollutants all are in the same solubility ranges as metals in the combined data base.)

LS&F mean values for Cd, Cr, Ni, Zn, and Fe, appearing in Table VII-19, are derived from plants A and B, as discussed above. The Cd value is from Plant C. One-, ten-, and 30-day values for LS&F are derived by applying the same variability factor developed from the pooled L&S data base for the specific pollutant to the LS&F mean calculated for that pollutant. EPA used variability factors calculated from the pooled metals data base because the pooled data base provided a better statistical basis for computing variability than the data from the three plants sampled. In fact, the use of the lime and settle combined data base variability factors is probably a conservative assumption because filtration is a less variable technology than lime and settle, since it is less operator dependent.

Mean values for LS&F for pollutants not already discussed are derived by reducing the L&S mean by one-third. The one-third reduction was established after examining the percent reduction in concentrations going from L&S to LS&F data for Cd, Cr, Ni, Zn, and Fe. The average reduction is 0.3338 or one-third. Variability factors for these additional pollutants are identical to the variabilities established for L&S treatment of these pollutants (using the variance from the pooled metals data base or the mean of other pollutant variances if a pollutant-specific variance is not available). Since filtration is a non-preferential technology with regard to metals treated, and furthermore is being used to polish relatively clean wastewater (wastewater after lime and settle treatment), EPA believes it is reasonable that these additional pollutants will be removed at the same average rate.

Copper concentrations achieved at plants A and B may be lower than generally achievable by plants in this category because of the high iron content and low copper content of the raw wastewaters. Therefore, the mean concentration value achieved is not used; the LS&F mean used is derived from the L&S technology using the one-third factor described previously.

L&S cyanide mean concentrations shown in Table VII-8 are ratioed to one-day, ten-day, and 30-day values using the mean variability factors developed for the additional pollutants not included in the pooled metals data base. The LS&F mean cyanide value is calculated by using the one-third removal factor for LS&F from the L&S mean removal, as discussed previously for LS&F metals limitations. The cyanide performance was arrived at by using the same variability factors. The treatment method used here is cyanide precipitation. Because cyanide precipitation is limited by the same physical processes as the metal precipitation, it is expected that the variabilities will be similar. Therefore, the average of the metal variability factors from the pooled metals data has been used as a basis for calculating the cyanide one-day, ten-day, and 30-day average treatment effectiveness values.

The filter performance for removing TSS as shown in Table VII-9 yields a mean effluent concentration of 2.61 mg/l and calculates to a ten-day average of 4.33, 30-day average of 3.36 mg/l; a one-day maximum of 8.88. These calculated values more than amply support the classic values of 10 and 15, respectively, which are used for LS&F.

Although iron was reduced in some LS&F operations, some facilities using that treatment introduce iron compounds to aid settling. Therefore, the one-day, ten-day, and 30-day values for iron at LS&F were held at the L&S level so as to not unduly penalize the operations which use the relatively less objectionable iron compounds to enhance removals of toxic metals.

Ammonia Steam Stripping Performance

Chemical analysis data were collected of raw waste (treatment influent) and treated waste (treatment effluent) from one plant of the iron and steel category. A contractor for EPA, using EPA sampling and chemical analysis protocols, collected six paired samples in a two-month period. These data are the data base for determining the effectiveness of ammonia steam stripping technology and are contained within the public record supporting this document. Ammonia treatment at this coke plant consisted of two steam stripping columns in series with steam injected countercurrently to the flow of the wastewater. A lime reactor for pH adjustment separated the two stripping columns.

An arithmetic mean of the treatment effluent data produced an ammonia long-term mean value of 32.2 mg/l. The one-day maximum, 10-day and 30-day average concentrations attainable by ammonia steam stripping were calculated using the long-term mean of the 32.2 mg/l and the variability factors developed for the combined metals data base. This produced ammonia concentrations of 133.3, 58.6 and 52.1 mg/l ammonia for the one-day maximum, 10-day and 30-day averages, respectively.

As discussed above under Demonstration Status for Ammonia Stripping (p.217), steam stripping is demonstrated within the nonferrous metals manufacturing category. EPA believes the performance data from the iron and steel category provide a valid measure of this technology's performance on nonferrous category wastewater due to similar (concentrations of the same order of magnitude) concentrations of ammonia in the respective raw wastewater matrices. A comparison of raw untreated wastewater samples from the nonferrous metals manufacturing point source category and the iron and steel facility from which the ammonia data was transferred is shown below:

Category or Subcategory	Ammonia Concentrations (mg/l)
Iron and Steel	599, 226, 819, 502, 984, and 797
Primary Tungsten	695 and 1,610
Primary Columbium-Tantalum	53.1, 496.1, 25,700, 18,500 and 16,900
Secondary Aluminum	195
Secondary Silver	1,202 and 4,630

Activated Carbon Performance

Activated carbon preliminary treatment was selected to control discharges of polynuclear aromatic hydrocarbons from wet air pollution control associated with anode paste plants, anode bake plants, potlines, and potrooms, as well as the cathode reprocessing operations from primary aluminum plants. This treatment technology was selected because discharges from these operations do not appear to be effectively controlled by existing treatment. Activated carbon is not demonstrated in this or any other application within the primary aluminum subcategory. Therefore, performance of this technology is transferred from the iron and steel category.

MINOR TECHNOLOGIES

Several other treatment technologies were considered for possible application in BPT or BAT. These technologies are presented here with a full discussion for most of them. A few are described only briefly because of limited technical development.

Flotation

Flotation is the process of causing particles such as metal hydroxides or oil to float to the surface of a tank where they can be concentrated and removed. This is accomplished by releasing gas bubbles which attach to the solid particles, increasing their buoyancy and causing them to float. In principle, this process is the opposite of sedimentation. Figure VII-20 shows one type of flotation system.

Flotation is used primarily in the treatment of wastewater streams that carry heavy loads of finely divided suspended solids or oil. Solids having a specific gravity only slightly greater than 1.0, which would require abnormally long sedimentation times, may be removed in much less time by flotation.

This process may be performed in several ways: foam, dispersed air, dissolved air, gravity, and vacuum flotation are the most commonly used techniques. Chemical additives are often used to enhance the performance of the flotation process.

The principal difference among types of flotation is the method of generating the minute gas bubbles (usually air) in a suspension of water and small particles. Chemicals may be used to improve the efficiency with any of the basic methods. The following paragraphs describe the different flotation techniques and the method of bubble generation for each process.

Froth Flotation - Froth flotation is based on differences in the physiochemical properties in various particles. Wettability and surface properties affect the ability of the particles to attach themselves to gas bubbles in an aqueous medium. In froth flotation, air is blown through the solution containing flotation reagents. The particles with water repellant surfaces stick to air bubbles as they rise and are brought to the surface. A mineralized froth layer, with mineral particles attached to air bubbles, is formed. Particles of other minerals which are readily wetted by water do not stick to air bubbles and remain in suspension.

Dispersed Air Flotation - In dispersed air flotation, gas bubbles are generated by introducing the air by means of mechanical agitation with impellers or by forcing air through porous media. Dispersed air flotation is used mainly in the metallurgical industry.

Dissolved Air Flotation - In dissolved air flotation, bubbles are produced by releasing air from a superstaturated solution under relatively high pressure. There are two types of contact between the gas bubbles and particles. The first type is predominant in the flotation of flocculated materials and involves the entrapment of rising gas bubbles in the flocculated particles as they increase in size. The bond between the bubble and particle is one of physical capture only. The second type of contact is one of adhesion. Adhesion results from the intermolecular attraction exerted at the interface between the solid particle and the gaseous bubble.

Vacuum Flotation - This process consists of saturating the wastewater with air either directly in an aeration tank, or by permitting air to enter on the suction of a wastewater pump. A partial vacuum is applied, which causes the dissolved air to come out of solution as minute bubbles. The bubbles attach to solid particles and rise to the surface to form a scum blanket, which is normally removed by a skimming mechanism. Grit and other heavy solids that settle to the bottom are generally raked to a central sludge pump for removal. A typical vacuum flotation unit consists of a covered cylindrical tank in which a partial vacuum is maintained. The tank is equipped with scum and sludge removal mechanisms. The floating material is continuously swept to the tank periphery, automatically discharged into a scum trough, and removed from the unit by a pump also under partial vacuum. Auxiliary equipment includes an aeration tank for saturating the wastewater with air, a tank with a short retention time for removal of large bubbles, vacuum pumps, and sludge pumps.

Application and Performance. Flotation is used primarily in the treatment of wastewater streams that carry heavy loads of finely divided suspended solids or oil. Solids having a specific gravity only slightly greater than 1.0, which would require abnormally long sedimentation times, may be removed in much less time by flotation.

The primary variables for flotation design are pressure, feed solids concentration, and retention period. The suspended solids in the effluent decrease, and the concentration of solids in the float increases, with increasing retention period. When the flotation process is used primarily for clarification, a retention period of 20 to 30 minutes is adequate for separation and concentration.

Advantages and Limitations. Some advantages of the flotation process are the high levels of solids separation achieved in many applications, the relatively low energy requirements, and the adaptability to meet the treatment requirements of different waste types. Limitations of flotation are that it often requires addition of chemicals to enhance process performance and that it generates large quantities of solid waste.

Operational Factors. Reliability: Flotation systems normally are very reliable with proper maintenance of the sludge collector mechanism and the motors and pumps used for aeration.

Maintainability: Routine maintenance is required on the pumps and motors. The sludge collector mechanism is subject to possible corrosion or breakage and may require periodic replacement.

Solid Waste Aspects: Chemicals are commonly used to aid the flotation process by creating a surface or a structure that can easily adsorb or entrap air bubbles. Inorganic chemicals, such as the aluminum and ferric salts, and activated silica, can bind the particulate matter together and create a structure that can entrap air bubbles. Various organic chemicals can change the nature of either the air-liquid interface or the solid-liquid interface, or both. These compounds usually collect on the interface to bring about the desired changes. The added chemicals plus the particles in solution combine to form a large volume of sludge which must be further treated or properly disposed.

Demonstration Status. Flotation is a fully developed process and is readily available for the treatment of a wide variety of industrial waste streams. Dissolved air flotation technology is used by can manufacturing plants to remove oil and grease in the wastewater from can wash lines. It is not currently used to treat nonferrous metals manufacturing wastewaters.

Centrifugation

Centrifugation is the application of centrifugal force to separate solids and liquids in a liquid-solid mixture or to effect concentration of the solids. The application of centrifugal force is effective because of the density differential normally found between the insoluble solids and the liquid in which they are contained. As a waste treatment procedure, centrifugation is most often applied to dewatering of sludges. One type of centrifuge is shown in Figure VII-21.

There are three common types of centrifuges: the disc, basket, and conveyor type. All three operate by removing solids under the influence of centrifugal force. The fundamental difference between the three types is the method by which solids are collected in and discharged from the bowl.

In the disc centrifuge, the sludge feed is distributed between narrow channels that are present as spaces between stacked conical discs. Suspended particles are collected and discharged continuously through small orifices in the bowl wall. The clarified effluent is discharged through an overflow weir.

A second type of centrifuge which is useful in dewatering sludges is the basket centrifuge. In this type of centrifuge, sludge feed is introduced at the bottom of the basket, and solids collect at the bowl wall while clarified effluent overflows the lip ring at the top. Since the basket centrifuge does not have provision for continuous discharge of collected cake, operation requires interruption of the feed for cake discharge for a minute or two in a 10 to 30 minute overall cycle.

The third type of centrifuge commonly used in sludge dewatering is the conveyor type. Sludge is fed through a stationary feed pipe into a rotating bowl in which the solids are settled out against the bowl wall by centrifugal force. From the bowl wall, they are moved by a screw to the end of the machine, at which point they are discharged. The liquid effluent is discharged through ports after passing the length of the bowl under centrifugal force.

Application and Performance. Virtually all industrial waste treatment systems producing sludge can use centrifugation to dewater it. Centrifugation is currently being used by a wide range of industrial concerns.

The performance of sludge dewatering by centrifugation depends on the feed rate, the rotational velocity of the drum, and the sludge composition and concentration. Assuming proper design and operation, the solids content of the sludge can be increased to 20 to 35 percent.

Advantages and Limitations. Sludge dewatering centrifuges have minimal space requirements and show a high degree of effluent clarification. The operation is simple, clean, and relatively inexpensive. The area required for a centrifuge system installation is less than that required for a filter system or sludge drying bed of equal capacity, and the initial cost is lower.

Centrifuges have a high power cost that partially offsets the low initial cost. Special consideration must also be given to providing sturdy foundations and soundproofing because of the vibration and noise that result from centrifuge operation. Adequate electrical power must also be provided since large motors are required. The major difficulty encountered in the operation of centrifuges has been the disposal of the concentrate which is relatively high in suspended, non-settling solids.

Operational Factors. Reliability: Centrifugation is highly reliable with proper control of factors such as sludge feed, consistency, and temperature. Pretreatment such as grit removal and coagulant addition may be necessary, depending on the composition of the sludge and on the type of centrifuge used.

Maintainability: Maintenance consists of periodic lubrication, cleaning, and inspection. The frequency and degree of inspection required varies depending on the type of sludge solids being dewatered and the maintenance service conditions. If the sludge is abrasive, it is recommended that the first inspection of the rotating assembly be made after approximately 1,000 hours of operation. If the sludge is not abrasive or corrosive, then the initial inspection might be delayed. Centrifuges not equipped with a continuous sludge discharge system require periodic shutdowns for manual sludge cake removal.

Solid Waste Aspects: Sludge dewatered in the centrifugation process may be disposed of by landfill. The clarified effluent (centrate), if high in dissolved or suspended solids, may require further treatment prior to discharge.

Demonstration Status. Centrifugation is currently used in a great many commercial applications to dewater sludge. One secondary copper plant uses a centrifuge to dewater sludge. Work is underway to improve the efficiency, increase the capacity, and lower the costs associated with centrifugation.

Coalescing

The basic principle of coalescence involves the preferential wetting of a coalescing medium by oil droplets which accumulate on the medium and then rise to the surface of the solution as they combine to form larger particles. The most important requirements for coalescing media are wettability for oil and large surface area. Monofilament line is sometimes used as a coalescing medium.

Coalescing stages may be integrated with a wide variety of gravity oil separation devices, and some systems may incorporate several coalescing stages. In general, a preliminary oil skimming step is desirable to avoid overloading the coalescer.

One commercially marketed system for oily waste treatment combines coalescing with inclined plant separation and filtration. In this system, the oily wastes flow into an inclined plate settler. This unit consists of a stack of inclined baffle plates in a cylindrical container with an oil collection chamber at the top. The oil droplets rise and impinge upon the undersides of the plants. They then migrate upward to a guide rib that directs the oil to the oil collection chamber, from which oil is discharged for reuse or disposal.

The oily water continues on through another cylinder containing replaceable filter cartridges that remove suspended particles from the waste. From there the wastewater enters a final cylinder in which the coalescing material is housed. As the oily water passes through the many small, irregular, continuous passages in the coalescing material, the oil droplets coalesce and rise to an oil collection chamber.

Application and Performance. Coalescing is used to treat oily wastes that do not separate readily in simple gravity systems. The three stage system described above has achieved effluent concentrations of 10 to 15 mg/l oil and grease from raw waste concentrations of 1,000 mg/l or more.

Advantages and Limitations. Coalescing allows removal of oil droplets too finely dispersed for conventional gravity separation-skimming technology. It also can significantly reduce the residence times (and therefore separator volumes) required to achieve separation of oil from some wastes. Because of its simplicity, coalescing provides generally high reliability and low capital and operating costs. Coalescing is not generally effective in removing soluble or chemically stabilized emulsified oils. To avoid plugging, coalescers must be protected by pretreatment from the very high concentrations of free oil and grease and suspended solids. Frequent replacement of prefilters may be necessary when raw waste oil concentrations are high.

Operational Factors. Reliability: Coalescing is inherently highly reliable since there are no moving parts and the coalescing substrate (monofilament, etc.) is inert in the process and therefore not subject to frequent regeneration or replacement requirements. Large loads or inadequate preliminary treatment; however, may result in plugging or bypass of coalescing stages.

Maintainability: Maintenance requirements are generally limited to replacement of the coalescing medium on an infrequent basis.

Solid Waste Aspects: No appreciable solid waste is generated by this process.

Demonstration Status. Coalescing has been fully demonstrated in industries generating oily wastewater, although none are known to be in use at any nonferrous metals manufacturing facility.

Cyanide Oxidation by Chlorine

Cyanide oxidation using chlorine is widely used in industrial waste treatment to oxidize cyanide. Chlorine can be utilized in either the elemental or hypochlorite forms. This classic procedure can be illustrated by the following two step chemical reaction:

1. $Cl_2 + NaCN + 2NaOH \rightarrow NaCNO + 2NaCl + H_2O$

2. $3Cl_2 + 6NaOH + 2NaCNO \rightarrow 2NaHCO_3 + N_2 + 6NaCl + 2H_2O$

The reaction presented as equation (2) for the oxidation of cyanate is the final step in the oxidation of cyanide. A complete system for the alkaline chlorination of cyanide is shown in Figure VII-22.

The alkaline chlorination process oxidizes cyanides to carbon dioxide and nitrogen. The equipment often consists of an equalization tank followed by two reaction tanks, although the reaction can be carried out in a single tank. Each tank has an electronic recorder-controller to maintain required conditions with respect to pH and oxidation reduction potential (ORP). In the first reaction tank, conditions are adjusted to oxidize cyanides to cyanates. To effect the reaction, chlorine is metered to the reaction tank as required to maintain the ORP in the range of 350 to 400 millivolts, and 50 percent aqueous caustic soda is added to maintain a pH range of 9.5 to 10. In the second reaction tank, conditions are maintained to oxidize cyanate to carbon dioxide and nitrogen. The desirable ORP and pH for this reaction are 600 millivolts and a pH of 8.0. Each of the reaction tanks is equipped with a propeller agitator designed to provide approximately one turnover per minute. Treatment by the batch process is accomplished by using two tanks, one for collection of water over a specified time period, and one tank for the treatment of an accumulated batch. If dumps of concentrated wastes are frequent, another tank may be required to equalize the flow to the treatment tank. When the holding tank is full, the liquid is transferred to the reaction tank for treatment. After treatment, the supernatant is discharged and the sludges are collected for removal and ultimate disposal.

Application and Performance. The oxidation of cyanide waste by chlorine is a classic process and is found in most industrial plants using cyanide. This process is capable of achieving effluent levels of free cyanide that are nondetectable.

Advantages and Limitations. Some advantages of chlorine oxidaton for handling process effluents are operation at ambient temperature, suitability for automatic control, and low cost. Disadvantages include the need for careful pH control, possible chemical interference in the treatment of mixed wastes, and the potential hazard of storing and handling chlorine gas. If organic compounds are present, toxic chlorinated organics may be generated. Alkaline chlorination is not effective in treating metallocyanide complexes, such as the ferrocyanide.

Operational Factors. Reliability: Chlorine oxidation is highly reliable with proper monitoring and control, and proper pretreatment to control interfering substances.

Maintainability: Maintenance consists of periodic removal of sludge and recalibration of instruments.

Solid Waste Aspects: There is no solid waste problem associated with chlorine oxidation.

Demonstration Status. The oxidation of cyanide wastes by chlorine is a widely used process in plants using cyanide in cleaning and metal processing baths.

Cyanide Oxidation by Ozone

Ozone is a highly reactive oxidizing agent which is approximately 10 times more soluble than oxygen on a weight basis in water. Ozone may be produced by several methods, but the silent electrical discharge method is predominant in the field. The silent electrical discharge process produces ozone by passing oxygen or air between electrodes separated by an insulating material. A complete ozonation system is represented in Figure VII-23.

Application and Performance. Ozonation has been applied commercially to oxidize cyanides, phenolic chemicals, and organometal complexes. Its applicability to photographic wastewaters has been studied in the laboratory with good results. Ozone is used in industrial waste treatment primarily to oxidize cyanide to cyanate and to oxidize phenols and dyes to a variety of colorless nontoxic products.

Oxidation of cyanide to cyanate is illustrated below:

$$CN^- + O_3 \rightarrow CNO^- + O_2$$

Continued exposure to ozone will convert the cyanate formed to carbon dioxide and ammonia; however, this is not economically practical.

Ozone oxidation of cyanide to cyanate requires 1.8 to 2.0 pounds ozone per pound of CN^-; complete oxidation requires 4.6 to 5.0 pounds ozone per pound of CN^-. Zinc, copper, and nickel cyanides are easily destroyed to a nondetectable level, but cobalt and iron cyanides are more resistant to ozone treatment.

Advantages and Limitations. Some advantages of ozone oxidation for handling process effluents are its suitability to automatic control and on-site generation and the fact that reaction products are not chlorinated organics and no dissolved solids are added in the treatment step. Ozone in the presence of activated carbon, ultraviolet, and other promoters shows promise of reducing reaction time and improving ozone utilization, but the process at present is limited by high capital expense, possible chemical interference in the treatment of mixed wastes, and an energy requirement of 25 kwh/kg of ozone generated. Cyanide is not economically oxidized with O_3 beyond the cyanate form.

Operational Factors. Reliability: Ozone oxidation is highly reliable with proper monitoring and control, and proper preliminary treatment to control interfering substances.

Maintainability: Maintenance consists of periodic removal of sludge, and periodic renewal of filters and desiccators required for the input of clean dry air; filter life is a function of input concentrations of detrimental constituents.

Solid Waste Aspects: Preliminary treatment to eliminate substances which will interfere with the process may be necessary. Dewatering of sludge generated in the ozone oxidation process or in an "in-line" process may be desirable prior to disposal.

Cyanide Oxidation by Ozone with UV Radiation

One of the modifications of the ozonation process is the simultaneous application of ultraviolet light and ozone for the treatment of wastewater, including treatment of halogenated organics. The combined action of these two forms produces reactions by photolysis, photosensitization, hydroxylation, oxygenation, and oxidation. The process is unique because several reactions and reaction species are active simultaneously.

Ozonation is facilitated by ultraviolet absorption because both the ozone and the reactant molecules are raised to a higher energy state so that they react more rapidly. In addition, free radicals for use in the reaction are readily hydrolyzed by the water present. The energy and reaction intermediates created by the introduction of both ultraviolet and ozone greatly reduce the amount of ozone required compared with a system using ozone alone. Figure VII-24 shows a three-stage UV-ozone system. A system to treat mixed cyanides requires preliminary treatment that involves chemical coagulation, sedimentation, clarification, equalization, and pH adjustment.

Application and Performance. The ozone-UV radiation process was developed primarily for cyanide treatment in the electroplating and color photo-processing areas. It has been successfully applied to mixed cyanides and organics from organic chemicals manufacturing processes. The process is particularly useful for treatment of complexed cyanides such as ferricyanide, copper cyanide, and nickel cyanide, that are resistant to ozone.

Demonstration Status. Ozone combined with UV radiation is a relatively new technology. Four units are currently in operation and all four treat cyanide-bearing waste.

Cyanide Oxidation by Hydrogen Peroxide

Hydrogen peroxide oxidation removes both cyanide and metals in cyanide-containing wastewaters. In this process, cyanide-bearing waters are heated to 49°C to 54°C (120°F to 130°F) and the pH is adjusted to 10.5 to 11.8. Formalin (37 percent formaldehyde) is added while the tank is vigorously agitated. After two to five minutes, a proprietary peroxygen compound (41 percent hydrogen peroxide with a catalyst and additives) is added. After an hour of mixing, the reaction is complete. The cyanide is converted to cyanate and the metals are precipitated as oxides or hydroxides. The metals are then removed from solution by either settling or filtration.

The main equipment required for this process is two holding tanks equipped with heaters and air spargers or mechanical stirrers. These tanks may be used in a batch or continuous fashion, with one tank being used for treatment while the other is being filled. A settling tank or a filter is needed to concentrate the precipitate.

Application and Performance. The hydrogen peroxide oxidation process is applicable to cyanide-bearing wastewaters, especially those containing metal-cyanide complexes. In terms of waste reduction performance, this process can reduce total cyanide to less than 0.1 mg/l and the zinc or cadmium concentrations to less than 1.0 mg/l.

Advantages and Limitations. Chemical costs are similar to those for alkaline chlorination using chlorine and lower than those for treatment with hypochlorite. All free cyanide reacts and is completely oxidized to the less toxic cyanate state. In addition, the metals precipitate and settle quickly, and they may be recoverable in many instances; however, the process requires energy expenditures to heat the wastewater prior to treatment.

Demonstration Status. This treatment process was introduced in 1971 and is used in several facilities. No nonferrous metals manufacturing plants use oxidation by hydrogen peroxide.

Evaporation

Evaporation is a concentration process. Water is evaporated from a solution, increasing the concentration of solute in the remaining solution. If the resulting water vapor is condensed back to liquid water, the evaporation-condensation process is called distillation. However, to be consistent with industry terminology, evaporation is used in this report to describe both processes. Both atmospheric and vacuum evaporation are commonly used in industry today. Specific evaporation techniques are shown in Figure VII-25 and discussed below.

Atmospheric evaporation could be accomplished simply by boiling the liquid. To aid evaporation, heated liquid is sprayed on an evaporation surface, and air is blown over the surface and subsequently released to the atmosphere. Thus, evaporation occurs by humidification of the air stream, similar to a drying process. Equipment for carrying out atmospheric evaporation is quite similar for most applications. The major element is generally a packed column with an accumulator bottom. Accumulated wastewater is pumped from the base of the column, through a heat exchanger, and back into the top of the column, where it is sprayed into the packing. At the same time, air drawn upward through the packing by a fan is heated as it contacts the hot liquid. The liquid partially vaporizes and humidifies the air stream. The fan then blows the hot, humid air to the outside atmosphere. A scrubber is often unnecessary because the packed column itself acts as a scrubber.

Another form of atmospheric evaporator also works on the air humidification principle, but the evaporated water is recovered for reuse by condensation. These air humidification techniques operate well below the boiling point of water and can utilize waste process heat to supply the energy required.

In vacuum evaporation, the evaporation pressure is lowered to cause the liquid to boil at reduced temperatures. All of the water vapor is condensed and, to maintain the vacuum condition, noncondensible gases (air in particular) are removed by a vacuum pump. Vacuum evaporation may be either single or double effect. In double effect evaporation, two evaporators are used, and the water vapor from the first evaporator (which may be heated by steam) is used to supply heat to the second evaporator. As it supplies heat, the water vapor from the first evaporator condenses. Approximately equal quantities of wastewater are evaporated in each unit; thus, the double effect system evaporates twice the amount of water that a single effect system does, at nearly the same cost in energy but with added capital cost and complexity. The double effect technique is thermodynamically possible because the second evaporator is maintained at lower pressure (higher vacuum) and, therefore, lower evaporation temperature. Another means of increasing energy efficiency is vapor recompression (thermal or mechanical), which enables heat to be transferred from the condensing water vapor to the evaporating wastewater. Vacuum evaporation equipment may be classified as submerged tube or climbing film evaporation units.

In the most commonly used submerged tube evaporator, the heating and condensing coil are contained in a single vessel to reduce capital cost. The vacuum in the vessel is maintained by an eductor-type pump, which creates the required vacuum by the flow of the condenser cooling water through a venturi. Wastewater accumulates in the bottom of the vessel, and it is evaporated by means of submerged steam coils. The resulting water vapor condenses as it contacts the condensing coils in the top of the vessel. The condensate then drips off the condensing coils into a collection trough that carries it out of the vessel. Concentrate is removed from the bottom of the vessel.

The major elements of the climbing film evaporator are the evaporator, separator, condenser, and vacuum pump. Wastewater is "drawn" into the system by the vacuum so that a constant liquid level is maintained in the separator. Liquid enters the steam-jacketed evaporator tubes, and part of it evaporates so that a mixture of vapor and liquid enters the separator. The design of the separator is such that the liquid is continuously circulated from the separator to the evaporator. The vapor entering the separator flows out through a mesh entrainment separator to the condenser, where it is condensed as it flows down through the condenser tubes. The condensate, along with any entrained air, is pumped out of the bottom of the condenser by a liquid ring vacuum pump. The liquid seal provided by the condensate keeps the vacuum in the system from being broken.

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Application and Performance. Both atmospheric and vacuum evaporation are used in many industrial plants, mainly for the concentration and recovery of process solutions. Many of these evaporators also recover water for rinsing. Evaporation has also been applied to recovery of phosphate metal-cleaning solutions.

In theory, evaporation should yield a concentrate and a deionized condensate. Actually, carry-over has resulted in condensate metal concentrations as high as 10 mg/l, although the usual level is less than 3 mg/l. Samples from one plant showed 1,900 mg/l zinc in the feed, 4,570 mg/l in the concentrate, and 0.4 mg/l in the condensate. Another plant had 416 mg/l copper in the feed and 21,800 mg/l in the concentrate. Chromium analysis for that plant indicated 5,060 mg/l in the feed and 27,500 mg/l in the concentrate. Evaporators are available in a range of capacities, typically from 15 to 75 gph, and may be used in parallel arrangements for processing of higher flow rates.

Advantages and Limitations. Advantages of the evaporation process are that it permits recovery of a wide variety of process chemicals, and it is often applicable to concentration or removal of compounds which cannot be accomplished by any other means. The major disadvantage is that the evaporation process consumes relatively large amounts of energy for the evaporation of water. The recovery of waste heat from many industrial processes (e.g., diesel generators, incinerators, boilers, and furnaces) should be considered as a source of this heat for a totally integrated evaporation system. Also, in some cases solar heating could be inexpensively and effectively applied to evaporation units. For some applications, preliminary treatment may be required to remove solids or bacteria which tend to cause fouling in the condenser or evaporator. The buildup of scale on the evaporator surfaces reduces the heat transfer efficiency and may present a maintenance problem or increase operating cost. It has been demonstrated that fouling of the heat transfer surfaces can be avoided or minimized for certain dissolved solids by maintaining a seed slurry which provides preferential sites for precipitate deposition. In addition, low temperature differences in the evaporator will eliminate nucleate boiling and supersaturation effects. Steam distillable impurities in the process stream are carried over with the product water and must be handled by preliminary or post treatment.

Operational Factors. Reliability: Proper maintenance will ensure a high degree of reliability for the system. Without such attention, rapid fouling or deterioration of vacuum seals may occur, especially when handling corrosive liquids.

Maintainability: Operating parameters can be automatically controlled. Preliminary treatment may be required, as well as periodic cleaning of the system. Regular replacement of seals, especially in a corrosive environment, may be necessary.

Solid Waste Aspects: With only a few exceptions, the process does not generate appreciable quantities of solid waste.

Demonstration Status. Evaporation is a fully developed, commercially available wastewater treatment system. It is used extensively to recover plating chemicals in the electroplating industry and a pilot scale unit has been used in connection with phosphating of aluminum. Proven performance in silver recovery indicates that evaporation could be a useful treatment operation for the photographic industry, as well as for metal finishing.

Gravity Sludge Thickening

In the gravity thickening process, dilute sludge is fed from a primary settling tank or clarifier to a thickening tank where rakes stir the sludge gently to densify it and to push it to a central collection well. The supernatant is returned to the primary settling tank. The thickened sludge that collects on the bottom of the tank is pumped to dewatering equipment or hauled away. Figure VII-26 shows the construction of a gravity thickener.

Application and Performance. Thickeners are generally used in facilities where the sludge is to be further dewatered by a compact mechanical device such as a vacuum filter or centrifuge. Doubling the solids content in the thickener substantially reduces capital and operating cost of the subsequent dewatering device and also reduces cost for hauling. The process is potentially applicable to almost any industrial plant.

Organic sludges from sedimentation units of 1 to 2 percent solids concentration can usually be gravity thickened to 6 to 10 percent; chemical sludges can be thickened to 4 to 6 percent.

Advantages and Limitations. The principal advantage of a gravity sludge thickening process is that it facilitates further sludge dewatering. Other advantages are high reliability and minimum maintenance requirements.

Limitations of the sludge thickening process are its sensitivity to the flow rate through the thickener and the sludge removal rate. These rates must be low enough not to disturb the thickened sludge.

Operational Factors. Reliability: Reliability is high with proper design and operation. A gravity thickener is designed on the basis of square feet per pound of solids per day, in which the required surface area is related to the solids entering and leaving the unit. Thickener area requirements are also expressed in terms of mass loading, kilograms of solids per square meter per day (lbs/sq ft/day).

Maintainability: Twice a year, a thickener must be shut down for lubrication of the drive mechanisms. Occasionally, water must be pumped back through the system in order to clear sludge pipes.

Solid Waste Aspects: Thickened sludge from a gravity thickening process will usually require further dewatering prior to disposal, incineration, or drying. The clear effluent may be recirculated in part, or it may be subjected to further treatment prior to discharge.

Demonstration Status. Gravity sludge thickeners are used throughout industry to reduce sludge water content to a level where the sludge may be efficiently handled. Further dewatering is usually practiced to minimize costs of hauling the sludge to approved landfill areas.

Ion Exchange

Ion exchange is a process in which ions, held by electrostatic forces to charged functional groups on the surface of the ion exchange resin, are exchanged for ions of similar charge from the solution in which the resin is immersed. This is classified as a sorption process because the exchange occurs on the surface of the resin, and the exchanging ion must undergo a phase transfer from solution phase to solid phase. Thus, ionic contaminants in a waste stream can be exchanged for the harmless ions of the resin.

Although the precise technique may vary slightly according to the application involved, a generalized process description follows. The wastewater stream being treated passes through a filter to remove any solids, then flows through a cation exchanger which contains the ion exchange resin. Here, metallic impurities such as copper, iron, and trivalent chromium are retained. The stream then passes through the anion exchanger and its assocaited resin. Hexavalent chromium (in the form of chromate or dichromate), for example, is retained in this stage. If one pass does not reduce the contaminant levels sufficiencly, the stream may then enter another series of exchangers. Many ion exchange systems are equipped with more than one set of exchangers for this reason.

The other major portion of the ion exchange process concerns the regeneration of the resin, which now holds those impurities retained from the waste stream. An ion exchange unit with in-place regeneration is shown in Figure VII-27. Metal ions such as nickel are removed by an acid, cation exchange resin, which is regenerated with hydrochloric or sulfuric acid, replacing the metal ion with one or more hydrogen ions. Anions such as dichromate are removed by a basic anion exchange resin, which is regenerated with sodium hydroxide, replacing the anion with one or more hydroxyl ions. The three principal methods employed by industry for regenerating the spent resin are:

(A) Replacement Service: A regeneration service replaces the spent resin with regenerated resin, and regenerates the spent resin at its own facility. The service then has the problem of treating and disposing of the spent regenerant.

(B) In-Place Regeneration: Some establishments may find it less expensive to do their own regeneration. The spent resin column is shut down for perhaps an hour, and the spent resin is regenerated. This results in one or more waste streams which must be treated in an appropriate manner. Regeneration is performed as the resins require it, usually every few months.

(C) Cyclic Regeneration: In this process, the regeneration of the spent resins takes place within the ion exchange unit itself in alternating cycles with the ion removal process. A regeneration frequency of twice an hour is typical. This very short cycle time permits operation with a very small quantity of resin and with fairly concentrated solutions, resulting in a very compact system. Again, this process varies according to application, but the regeneration cycle generally begins with caustic being pumped through the anion exchanger, carrying out hexavalent chromium, for example, as sodium dichromate. The sodium dichromate stream then passes through a cation exchanger, converting the sodium dichromate to chromic acid. After concentration by evaporation or other means, the chromic acid can be returned to the process line. Meanwhile, the cation exchanger is regenerated with sulfuric acid, resulting in a waste acid stream containing the metallic impurities removed earlier. Flushing the exchangers with water completes the cycle. Thus, the wastewater is purified and, in this example, chromic acid is recovered. The ion exchangers, with newly regenerated resin, then enter the ion removal cycle again.

Application and Performance. The list of pollutants for which the ion exchange system has proven effective includes aluminum, arsenic, cadmium, chromium (hexavalent and trivalent), copper, cyanide, gold, iron, lead, manganese, nickel, selenium, silver, tin, zinc, and others. Thus, it can be applied to a wide variety of industrial concerns. Because of the heavy concentrations of metals in their wastewater, the metal finishing industries utilize ion exchange in several ways. As an end-of-pipe treatment, ion exchange is certainly feasible, but its greatest value is in recovery applications. It is commonly used as an integrated treatment to recover rinse water and process chemicals. Some electroplating facilities use ion exchange to concentrate and purify plating baths. Also, many industrial concerns use ion exchange to reduce salt concentrations in incoming water sources.

Ion exchange is highly efficient at recovering metal-bearing solutions. Recovery of chromium, nickel, phosphate solution, and sulfuric acid from anodizing is common. A chromic acid recovery efficiency of 99.5 percent has been demonstrated. Typical data for purification of rinse water are displayed in Table VII-23.

Advantages and Limitations. Ion exchange is a versatile technology applicable to a great many situations. This flexibility, along with its compact nature and performance, makes ion exchange a very effective method of wastewater treatment. However, the resins in these systems can prove to be a limiting factor. The thermal limits of the anion resins, generally in the vicinity of 60°C, could prevent its use in certain situations. Similarly, nitric acid, chromic acid, and hydrogen peroxide can all damage the resins, as will iron, manganese, and copper when present with sufficient concentrations of dissolved oxygen. Removal of a particular trace contaminant may be uneconomical because of the presence of other ionic species that are preferentially removed. The regeneration of the resins presents its own problems. The cost of the regenerative chemicals can be high. In addition, the waste streams originating from the regeneration process are extremely high in pollutant concentrations, although low in volume. These must be further processed for proper disposal.

Operational Factors. Reliability: With the exception of occasional clogging or fouling of the resins, ion exchange has proved to be a highly dependable technology.

Maintainability: Only the normal maintenance of pumps, valves, piping, and other hardware used in the regeneration process is required.

Solid Waste Aspects: Few, if any, solids accumulate within the ion exchangers, and those which do appear are removed by the regeneration process. Proper prior treatment and planning can eliminate solid buildup problems altogether. The brine resulting from regeneration of the ion exchange resin most usually must be treated to remove metals before discharge. This can generate solid waste.

Demonstration Status. All of the ion exchange applications discussed in this section are in commercial use, and industry sources estimate the number of ion exchange units currently in the field at well over 120. The research and development in ion exchange is focusing on improving the quality and efficiency of the resins, rather than new applications. Work is also being done on a continuous regeneration process whereby the resins are contained on a fluid- transfusible belt. The belt passes through a compartmented tank with ion exchange, washing, and regeneration sections. The resins are therefore continually used and regenerated. No such system, however, has been reported beyond the pilot stage.

Insoluble Starch Xanthate

Insoluble starch xanthate is essentially an ion exchange medium used to remove dissolved heavy metals from wastewater. The water may then either be reused (recovery application) or discharged (end-of-pipe application). In a commercial electroplating operation, starch xanthate is coated on a filter medium. Rinse water containing dragged out heavy metals is circulated through the filters and then reused for rinsing. The starch-heavy metal complex is disposed of and replaced periodically. Laboratory tests indicate that recovery of metals from the complex is feasible, with regeneration of the starch xanthate. Besides electroplating, starch xanthate is potentially applicable to nonferrous metals manufacturing, aluminum forming, coil coating, porcelain enameling, copper fabrication, and any other industrial plants where dilute metal wastewater streams are generated. Its present use is limited to one electroplating plant.

Peat Adsorption

Peat moss is a complex natural organic material containing lignin and cellulose as major constituents. These constituents, particularly lignin, bear polar functional groups, such as alcohols, aldehydes, ketones, acids, phenolic hydroxides, and ethers, that can be involved in chemical bonding. Because of the polar nature of the material, its adsorption of dissolved solids such as transition metals and polar organic molecules is quite high. These properties have led to the use of peat as an agent for the purification of industrial wastewater.

Peat adsorption is a "polishing" process which can achieve very low effluent concentrations for several pollutants. If the concentrations of pollutants are above 10 mg/l, then peat adsorption must be preceded by pH adjustment for metals precipitation and subsequent clarification. Pretreatment is also required for chromium wastes using ferric chloride and sodium sulfide. The wastewater is then pumped into a large metal chamber called a kier which contains a layer of peat through which the waste stream passes. The water flows to a second kier for further adsorption. The wastewater is then ready for discharge. This system may be automated or manually operated.

Application and Performance. Peat adsorption can be used in aluminum forming plants for removal of residual dissolved metals from clarifier effluent. Peat moss may be used to treat wastewaters containing heavy metals such as mercury, cadmium, zinc, copper, iron, nickel, chromium, and lead, as well as organic matter such as oil, detergents, and dyes. Peat adsorption is currently used commercially at a textile plant, a newsprint facility, and a metal reclamation operation.

Table VII-24 contains performance figures obtained from pilot plant studies. Peat adsorption was preceded by pH adjustment for precipitation and by clarification.

In addition, pilot plant studies have shown that chelated metal wastes, as well as the chelating agents themselves, are removed by contact with peat moss.

Advantages and Limitations. The major advantages of the system include its ability to yield low pollutant concentrations, its broad scope in terms of the pollutants eliminated, and its capacity to accept wide variations of wastewater composition.

Limitations include the cost of purchasing, storing, and disposing of the peat moss; the necessity for regular replacement of the peat may lead to high operation and maintenance costs. Also, the pH adjustment must be altered according to the composition of the waste stream.

Operational Factors. Reliability: The question of long-term reliability is not yet fully answered. Although the manufacturer reports it to be a highly reliable system, operating experience is needed to verify the claim.

Maintainability: The peat moss used in this process soon exhausts its capacity to adsorb pollutants. At that time, the kiers must be opened, the peat removed, and fresh peat placed inside. Although this procedure is easily and quickly accomplished, it must be done at regular intervals, or the system's efficiency drops drastically.

Solid Waste Aspects: After removal from the kier, the spent peat must be eliminated. If incineration is used, precautions should be taken to ensure that those pollutants removed from the water are not released again in the combustion process. Presence of sulfides in the spent peat, for example, will give rise to sulfur dioxide in the fumes from burning. The presence of significant quantities of toxic heavy metals in nonferrous metals manufacturing wastewater will in general preclude incineration of peat used in treating these wastes.

Demonstration Status. Only three facilities currently use commercial adsorption systems in the United States - a textile manufacturer, a newsprint facility, and a metal reclamation firm. No data have been reported showing the use of peat adsorption in nonferrous metals manufacturing plants.

Membrane Filtration

Membrane filtration is a treatment system for removing precipitated metals from a wastewater stream. It must therefore be preceded by those treatment techniques which will properly prepare the wastewater for solids removal. Typically, a membrane filtration unit is preceded by pH adjustment or sulfide addition for precipitation of the metals. These steps are followed by the addition of a proprietary chemical reagent which causes the precipitate to be non-gelatinous, easily dewatered, and highly stable. The resulting mixture of pretreated wastewater and reagent is continuously recirculated through a filter module and back into a recirculation tank. The filter module contains tubular membranes. While the reagent-metal hydroxide precipitate mixture flows through the inside of the tubes, the water and any dissolved salts permeate the membrane. When the recirculating slurry reaches a concentration of 10 to 15 percent solids, it is pumped out of the system as sludge.

Application and Performance. Membrane filtration appears to be applicable to any wastewater or process water containing metal ions which can be precipitated using hydroxide, sulfide, or carbonate precipitation. It could function as the primary treatment system, but also might find application as a polishing treatment (after precipitation and settling) to ensure continued compliance with metals limitations. Membrane filtration systems are being used in a number of industrial applications, particularly in the metal finishing area. They have also been used for heavy metals removal in the metal fabrication industry and the paper industry.

The permeate is claimed by one manufacturer to contain less than the effluent concentrations shown in Table VII-25, regardless of the influent concentrations. These claims have been largely substantiated by the analysis of water samples at various plants in various industries.

In the performance predictions for this technology, pollutant concentrations are reduced to the levels shown in Table VII-25 unless lower levels are present in the influent stream.

Advantages and Limitations. A major advantage of the membrane filtration system is that installations can use most of the conventional end-of-pipe systems that may already be in place. Removal efficiencies are claimed to be excellent, even with sudden variation of pollutant input rates; however, the effectiveness of the membrane filtration system can be limited by clogging of the filters. Because pH changes in the waste stream greatly intensify clogging problems, the pH must be carefully monitored and controlled. Clogging can force the shutdown of the system and may interfere with production. In addition, relatively high capital cost of this system may limit its use.

Operational Factors. Reliability: Membrane filtration has been shown to be a very reliable system, provided that the pH is strictly controlled. Improper pH can result in the clogging of the membrane. Also, surges in the flow rate of the waste stream must be controlled in order to prevent solids from passing through the filter and into the effluent.

Maintainability: The membrane filters must be regularly monitored, and cleaned or replaced as necessary. Depending on the composition of the waste stream and its flow rate, frequent cleaning of the filters may be required. Flushing with hydrochloric acid for six to 24 hours will usually suffice. In addition, the routine maintenance of pumps, valves, and other plumbing is required.

Solid Waste Aspects: When the recirculating reagent-precipitate slurry reaches 10 to 15 percent solids, it is pumped out of the system. It can then be disposed of directly to a landfill or it can undergo a dewatering process. Because this sludge contains toxic metals, it requires proper disposal.

Demonstration Status. There are more than 25 membrane filtration systems presently in use on metal finishing and similar wastewaters. Bench scale and pilot studies are being run in an attempt to expand the list of pollutants for which this system is known to be effective. There are no data on the use of membrane filtration in nonferrous metals manufacturing plants.

Reverse Osmosis

The process of osmosis involves the passage of a liquid through a semipermeable membrane from a dilute to a more concentrated solution. Reverse osmosis (RO) is an operation in which pressure is applied to the more concentrated solution, forcing the permeate to diffuse through the membrane and into the more dilute solution. This filtering action produces a concentrate and a permeate on opposite sides of the membrane. The concentrate can then be further treated or returned to the original production operation for continued use, while the permeate water can be recycled for use as clean water. Figure VII-28 depicts a reverse osmosis system.

As illustrated in Figure VII-29, there are three basic configurations used in commercially available RO modules: tubular, spiral-wound, and hollow fiber. All of these operate on the principle described above, the major difference being their mechanical and structural design characteristics.

The tubular membrane module uses a porous tube with a cellulose acetate membrane-lining. A common tubular module consists of a length of 2.5 cm (1 inch) diameter tube wound on a supporting spool and encased in a plastic shroud. Feed water is driven into the tube under pressures varying from 40 to 55 atm (600 to 800 psi). The permeate passes through the walls of the tube and is collected in a manifold while the concentrate is drained off at the end of the tube. A less widely used tubular RO module uses a straight tube contained in a housing, under the same operating conditions.

Spiral-wound membranes consist of a porous backing sandwiched between two cellulose acetate membrane sheets and bonded along three edges. The fourth edge of the composite sheet is attached to a large permeate collector tube. A spacer screen is then placed on top of the membrane sandwich and the entire stack is rolled around the centrally located tubular permeate collector. The rolled up package is inserted into a pipe able to withstand the high operating pressures employed in this process, up to 55 atm (800 psi) with the spiral-wound module. When the system is operating, the pressurized product water permeates the membrane and flows through the backing material to the central collector tube. The concentrate is drained off at the end of the container pipe and can be reprocessed or sent to further treatment facilities.

The hollow fiber membrane configuration is made up of a bundle of polyamide fibers of approximately 0.0075 cm (0.003 in.) OD and 0.043 cm (0.0017 in.) ID. A commonly used hollow fiber module contains several hundred thousand of the fibers placed in a long tube, wrapped around a flow screen, and rolled into a spiral. The fibers are bent in a U-shape and their ends are supported by an epoxy bond. The hollow fiber unit is operated under 27 atm (400 psi), the feed water being dispersed from the center of the module through a porous distributor tube. Permeate flows through the membrane to the hollow interiors of the fibers and is collected at the ends of the fibers.

The hollow fiber and spiral-wound modules have a distinct advantage over the tubular system in that they are able to load a very large membrane surface area into a relatively small volume. However, these two membrane types are much more susceptible to fouling than the tubular system, which has a larger flow channel. This characteristic also makes the tubular membrane much easier to clean and regenerate than either the spiral-wound or hollow fiber modules. One manufacturer claims that their helical tubular module can be physically wiped clean by passing a soft porous polyurethane plug under pressure through the module.

Application and Performance. The largest application has been for the recovery of nickel solutions. It has been shown that RO can generally be applied to most acid metal baths with a high degree of performance, providing that the membrane unit is not overtaxed. The limitations most critical here are the allowable pH range and maximum operating pressure for each particular configuration.

Adequate prefiltration is also essential. Only three membrane types are readily available in commercial RO units, and their overwhelming use has been for the recovery of various acid metal baths. For the purpose of calculating performance predictions of this technology, a rejection ratio of 98 percent is assumed for dissolved salts, with 95 percent permeate recovery.

Advantages and Limitations. The major advantage of reverse osmosis for handling process effluents is its ability to concentrate dilute solutions for recovery of salts and chemicals with low power requirements. No latent heat of vaporization or fusion is required for effecting separations; the main energy requirement is for a high pressure pump. It requires relatively little floor space for compact, high capacity units, and it exhibits good recovery and rejection rates for a number of typical process solutions.

A limitation of the reverse osmosis process for treatment of process effluents is its limited temperature range for satisfactory operation. For cellulose acetate systems, the preferred limits are 18°C to 30°C (65°F to 85°F); higher temperatures will increase the rate of membrane hydrolysis and reduce system life, while lower temperatures will result in decreased fluxes with no damage to the membrane.

Another limitation is inability to handle certain solutions. Strong oxidizing agents, strongly acidic or basic solutions, solvents, and other organic compounds can cause dissolution of the membrane. Poor rejection of some compounds such as borates and low molecular weight organics is another problem. Fouling of membranes by slightly soluble components in solution or colloids has caused failures, and fouling of membranes by feed waters with high levels of suspended solids can be a problem. A final limitation is inability to treat or achieve high concentration with some solutions. Some concentrated solutions may have initial osmotic pressures which are so high that they either exceed available operating pressures or are uneconomical to treat.

Operational Factors. Reliability: Acceptable reliability can be achieved so long as the proper precautions are taken to minimize the chances of fouling or degrading the membrane. Sufficient testing of the waste stream is the best method of ensuring a successful application.

Maintainability: Membrane life is estimated to range from six months to three years, depending on the use of the system. Down time for flushing or cleaning is on the order of two hours as often as once each week; a substantial portion of maintenance time must be spent on cleaning any prefilters installed ahead of the reverse osmosis unit.

Solid Waste Aspects: In a closed loop system utilizing RO there is a constant recycle of permeate and a minimal amount of solid waste. Prefiltration eliminates many solids before they reach the module and helps keep the buildup to a minimum. These solids require proper disposal.

Demonstration Status. There are presently at least one hundred reverse osmosis wastewater applications in a variety of industries. In addition to these, there are 30 to 40 units being used to provide pure process water for several industries. Despite the many types and configurations of membranes, only the spiral-wound cellulose acetate membrane has had widespread success in commercial applications.

One secondary lead plant installed reverse osmosis following a lime precipitation and sedimentation system for treating waste battery electrolyte prior to discharge. However, the reverse osmosis membranes became fouled and never operated satisfactorily. In addition, plant personnel could not achieve design throughput for the reverse osmosis system. The technology was never made fully operational by the plant.

Reverse osmosis has not been demonstrated in any other full-scale applications nor has it been demonstrated in bench- or pilot-scale applications in the category to achieve virtually complete recycle.

Sludge Bed Drying

As a waste treatment procedure, sludge bed drying is employed to reduce the water content of a variety of sludges to the point where they are amenable to mechanical collection and removal to a landfill. These beds usually consist of 15 to 45 cm (6 to 18 in.) of sand over a 30 cm (12 in.) deep gravel drain system made up of 3 to 6 mm (1/8 to 1/4 in.) graded gravel overlying drain tiles. Figure VII-30 shows the construction of a drying bed.

Drying beds are usually divided into sectional areas approximately 7.5 meters (25 ft) wide x 30 to 60 meters (100 to 200 ft) long. The partitions may be earth embankments, but more often are made of planks and supporting grooved posts.

To apply liquid sludge to the sand bed, a closed conduit or a pressure pipeline with valved outlets at each sand bed section is often employed. Another method of application is by means of an open channel with appropriately placed side openings which are controlled by slide gates. With either type of delivery system, a concrete splash slab should be provided to receive the falling sludge and prevent erosion of the sand surface.

Where it is necessary to dewater sludge continuously throughout the year regardless of the weather, sludge beds may be covered with a fiberglass reinforced plastic or other roof. Covered drying beds permit a greater volume of sludge drying per year in most climates because of the protection afforded from rain or snow and because of more efficient control of temperature. Depending on the climate, a combination of open and enclosed beds will provide maximum utilization of the sludge bed drying facilities.

Application and Performance. Sludge drying beds are a means of dewatering sludge from clarifiers and thickeners. They are widely used both in municipal and industrial treatment facilities.

Dewatering of sludge on sand beds occurs by two mechanisms: filtration of water through the bed and evaporation of water as a result of radiation and convection. Filtration is generally complete in one to two days and may result in solids concentrations as high as 15 to 20 percent. The rate of filtration depends on the drainability of the sludge.

The rate of air drying of sludge is related to temperature, relative humidity, and air velocity. Evaporation will proceed at a constant rate to a critical moisture content, then at a falling rate to an equilibrium moisture content. The average evaporation rate for a sludge is about 75 percent of that from a free water surface.

Advantages and Limitations. The main advantage of sludge drying beds over other types of sludge dewatering is the relatively low cost of construction, operation, and maintenance.

Its disadvantages are the large area of land required and long drying times that depend, to a great extent on climate and weather.

Operational Factors. Reliability: Reliability is high with favorable climatic conditions, proper bed design, and care to avoid excessive or unequal sludge application. If climatic conditions in a given area are not favorable for adequate drying, a cover may be necessary.

Maintainability: Maintenance consists basically of periodic removal of the dried sludge. Sand removed from the drying bed with the sludge must be replaced and the sand layer resurfaced.

The resurfacing of sludge beds is the major expense item in sludge bed maintenance, but there are other areas which may require attention. Underdrains occasionally become clogged and have to be cleaned. Valves or sludge gates that control the flow of sludge to the beds must be kept watertight. Provision for drainage of lines in winter should be provided to prevent damage from freezing. The partitions between beds should be tight so that sludge will not flow from one compartment to another. The outer walls or banks around the beds should also be watertight.

Solid Waste Aspects: The full sludge drying bed must either be abandoned or the collected solids must be removed to a landfill. These solids contain whatever metals or other materials were settled in the clarifier. Metals will be present as hydroxides, oxides, sulfides, or other salts. They have the potential for leaching and contaminating ground water, whatever the location of the semidried solids. Thus the abandoned bed or landfill should include provision for runoff control and leachate monitoring.

Demonstration Status. Sludge beds have been in common use in both municipal and industrial facilities for many years. However, protection of ground water from contamination is not always adequate.

Vacuum Filtration

In wastewater treatment plants, sludge dewatering by vacuum filtration generally uses cylindrical drum filters. These drums have a filter medium which may be cloth made of natural or synthetic fibers or a wire-mesh fabric. The drum is suspended above and dips into a vat of sludge. As the drum rotates slowly, part of its circumference is subject to an internal vacuum that draws sludge to the filter medium. Water is drawn through the porous filter cake thorugh the drum fabric to a discharge port, and the dewatered sludge, loosened by compressed air, is scraped from the filter mesh. Because the dewatering of sludge on vacuum filters is relatively expensive per kilogram of water removed, the liquid sludge is frequently thickened prior to processing. A vacuum filter is shown in Figure VII-31.

Application and Performance. Vacuum filters are frequently used both in municipal treatment plants and in a wide variety of industries. They are most commonly used in larger facilities, which may have a thickener to double the solids content of clarifier sludge before vacuum filtering. Often a precoat is used to inhibit filter blinding.

The function of vacuum filtration is to reduce the water content of sludge, so that the solids content increases from about 5 percent to between 20 and 30 percent, depending on the waste characteristics.

Advantages and Limitations. Although the initial cost and area requirement of the vacuum filtration system are higher than those of a centrifuge, the operating cost is lower, and no special provisions for sound and vibration protection need be made. The dewatered sludge from this process is in the form of a moist cake and can be conveniently handled.

Operational Factors. Reliability: Vacuum filter systems have proven reliable at many industrial and municipal treatment facilities. At present, the largest municipal installation is at the West Southwest wastewater treatment plant of Chicago, Illinois, where 96 large filters were installed in 1925, functioned approximately 25 years, and then were replaced with larger units. Original vacuum filters at Minneapolis-St. Paul, Minnesota now have over 28 years of continuous service, and Chicago has some units with similar or greater service life.

Maintainability: Maintenance consists of the cleaning or replacement of the filter media, drainage grids, drainage piping, filter pans, and other parts of the equipment. Experience in a number of vacuum filter plants indicates that maintenance consumes approximately 5 to 15 percent of the total time. If carbonate buildup or other problems are unusually severe, maintenance time may be as high as 20 percent. For this reason, it is desirable to maintain one or more spare units.

If intermittent operation is used, the filter equipment should be drained and washed each time it is taken out of service. An allowance for this wash time must be made in filtering schedules.

Solid Waste Aspects: Vacuum filters generate a solid cake which is usually trucked directly to landfill. All of the metals extracted from the plant wastewater are concentrated in the filter cake as hydroxides, oxides, sulfides, or other salts.

Demonstration Status. Vacuum filtration has been widely used for many years. It is a fully proven, conventional technology for sludge dewatering.

IN-PLANT TECHNOLOGY

The intent of in-plant technology for the nonferrous metals manufacturing point source category is to reduce or eliminate the waste load requiring end-of-pipe treatment and thereby improve the efficiency of an existing wastewater treatment system or reduce the requirements of a new treatment system. In-plant technology involves water conservation, automatic controls, good housekeeping practices, process modifications, and waste treatment.

Process Water Recycle

EPA is proposing BAT for most subcategories based on 90 percent recycle of wet air pollution control and contact cooling wastewater. The Agency has proposed a higher rate for certain waste streams where reported rates of recycle are even higher. Water is used in wet air pollution control systems to capture particulate matter or fumes evolved during manufacturing. Cooling water is used to remove excess heat from cast metal products.

Recycle is part of the technical basis for many of the promulgated regulations in the nonferrous metals manufacturing category. The Agency identified both demonstrated and feasible recycle opportunities as early as 1973 in proposed effluent limitations for secondary aluminum.

Recycling of process water is the practice of recirculating water to be used again for the same purpose. An example of recycling process water is the return of casting contact cooling water to the casting process after the water passes through a cooling tower. Two types of recycle are possible--recycle with a bleed stream (blowdown) and total recycle. Total recycle may be prohibited by the presence of dissolved solids. Dissolved solids (e.g., sulfates and chlorides) entering a totally recycled waste stream may precipitate, forming scale if the solubility limits of the dissolved solids are exceeded. A bleed stream may be necessary to prevent maintenance problems (pipe plugging or scaling, etc.) that would be created by the precipitation of dissolved solids. While the volume of bleed required is a function of the amount of dissolved solids in the waste stream, 10 percent bleed is a common value for a variety of process waste streams in the nonferrous metals manufacturing category. The recycle of process water is currently practiced where it is cost effective, where it is necessary due to water shortage, or where the local permitting authority has required it. Recycle, as compared to the once-through use of process water, is an effective method of conserving water.

Application and Performance. Required hardware necessary for recycle is highly site-specific. Basic items include pumps and piping. Additional materials are necessary if water treatment occurs before the water is recycled. These items will be discussed separately with each unit process. Chemicals may be necessary to control scale buildup, slime, and corrosion problems, especially with recycled cooling water.

The Agency based its zero discharge of pollutants regulation for PSES in the secondary copper subcategory on the use of cooling towers in conjunction with lime precipitation and sedimentation. The lime precipitation and sedimentation technology was included to reduce the metals concentrations so that the wastewater could be completely recycled and reused without corrosion and scaling problems. Maintenance and energy use are limited to that required by the pumps, and solid waste generation is dependent o the type of treatment system in place.

Recycling through cooling towers is the most common practice. One type of application is shown in Figure VII-32. Casting contact cooling water is recycled through a cooling tower with a blowdown discharge.

A cooling tower is a device which cools water by bringing the water into contact with air. The water and air flows are directed in such a way as to provide maximum heat transfer. The heat is transferred to air primarily by evaporation (about 75 percent), while the remainder is removed by sensible heat transfer.

Factors influencing the rate of heat transfer and, ultimately, the temperature range of the tower, include water surface area, tower packing and configuration, air flow, and packing height. large water surface area promotes evaporation, and sensible heat transfer rates are lower in proportion to the water surface area provided. Packing (an internal latticework contact area) is often used to produce small droplets of water which evaporate more easily, thus increasing the total surface area per unit of throughput. For a given water flow, increasing the air flow increases the amount of heat removed by maintaining higher thermodynamic potentials. The packing height in the tower shoul be high enough so that the air leaving the tower is close to saturation.

A mechanical-draft cooling tower consists of the following major components:

(1) Inlet-water distributor
(2) Packing
(3) Air fans
(4) Inlet-air louvers
(5) Drift or carryover eliminators
(6) Cooled water storage basin.

Advantages and Limitations. Recycle offers economic as well as environmental advantages. Water consumption is reduced and wastewater handling facilities (pumps, pipes, clarifiers, etc.) can thus be sized for smaller flows. By concentrating the pollutants in a much smaller volume (the bleed stream), greater removal efficiencies can be attained by any applied treatment technologies. Recycle may require some treatment such as sedimentation or cooling of water before it is reused.

The ultimate benefit of recycling process water is the reduction in total wastewater discharge and the associated advantages of lower flow streams. A potential problem is the buildup of dissolved solids which could result in scaling. Scaling can usually be controlled by depressing the pH and increasing the bleed flow.

Operational Factors. Reliability and Maintainability: Although the principal construction material in mechanical-draft towers is wood, other materials are used extensively. For long life and minimum maintenance, wood is generally pressure-treated with a preservative. Although the tower structure is usually made of treated redwood, a reasonable amount of treated fir has been used in recent years. Sheathing and louvers are generally made of asbestos cement, and the fan stacks of fiberglass. There is a trend to use fire-resistant extracted PVC as fill which, at little or no increase in cost, offers the advantage of permanent fire-resistant properties.

The major disadvantages of wood are its susceptibility to decay and fire. Steel construction is occasionally used, but not to any great extent. Concrete may be used but has relatively high construction labor costs, although it does offer the advantage of fire protection.

Various chemical additives are used in cooling water systems to control scale, slime, and corrosion. The chemical additives needed depend on the character of the make-up water. All additives have definite limitations and cannot eliminate the need for blowdown. Care should be taken in selecting nontoxic or readily degraded additives, if possible.

Solid Waste Aspects: The only solid waste associated with cooling towers may be removed scale.

Demonstration Status. Predominantly two types of waste streams in the nonferrous metals manufacturing category are currently being recycled; casting contact cooling water and air pollution control scrubber liquor. Two variations of recycle are used: (1) a wastewater is recycled within a given process, and (2) a wastewater is combined with others, treated, and the combined wastewater is recycled to the processes from which it originated.

For example, scrubber liquor may be recycled within the scrubber, or treated by sedimentation and recycled back to the scrubber. As a second example, plants in the primary aluminum subcategory combine wastewater from potline scrubbers and from cathode reprocessing for cryolite recovery, and recycle the treated wastewater back to the scrubbers.

Total recycle may become more wide-spread in the future if methods for removal of dissolved solids, such as reverse osmosis and ion exchange, become more common and less expensive.

The Agency observed extensive recycle of contact cooling water and scrubber liquor throughout the category. Indeed, some plants reported 100 percent recycle of process wastewater from these operations. The Agency believes, however, that most plants may have to discharge a portion of the recirculating flow to prevent the excessive buildup of dissolved solids unless dragout of solids in products or slags is sufficient to prevent this buildup.

Existing practice supports the selection of a 90 percent recycle rate. Twenty-nine of 61 aluminum smelting and forming plants practice greater than 90 percent recycle of the direct chill casting contact cooling water. Two of the five aluminum smelters practicing continuous rod casting recycle 90 percent or more of their contact cooling water. Four of eight primary aluminum plants using wet air pollution control on anode bake ovens, five of 11 plants using wet scrubbers on potlines, and three of eight plants using wet scrubbers for potrooms recycle 90 percent or more of their scrubber water.

Five of 10 primary electrolytic copper plants currently recycle 90 percent or more of their casting contact cooling water. Two of three primary zinc plants with leaching scrubbers recycle 90 percent or more. Two of five primary tungsten plants with scrubbers on reduction furnaces practice 90 percent or greater recycle. Six of seven secondary silver plants with furnace scrubbers currently recycle 90 percent or more of the scrubber water.

Process Water Reuse

Reuse of process water is the practice of recirculating water used in one production process for subsequent use in a different production process.

Application and Performance. Reuse of wastewater in a different proces can include using a relatively clean wastewater for another application, or using a relatively dirty water for an application where water quality is of no concern.

Advantages and Limitations. Advantages of reuse are similar to the advantages of recycle. Water consumption is reduced and wastewater treatment facilities can be sized for smaller flows. Also, in areas where water shortages occur, reuse is an effective means of conserving water.

Operational Factors. The hardware necessary for reuse of process wastewaters varies, depending on the specific application. The basic elements include pumps and piping. Chemical addition is not usually warranted, unless treatment is required prior to reuse. Maintenance and energy use are limited to that required by the pumps. Solid waste generated is dependent upon the type of treatment used and will be discussed separately with each unit process.

Demonstration Status. Reuse applications in the nonferrous metals manfuacturing category are varied. For example, a primary aluminum plant reuses wastewater from casting for air scrubbing. A lead smelter uses wastewater from air scrubbing for slag granulation, where all the water is evaporated. A primary copper refinery reuses precipitated spent electrolyte, known as "black acid," in leaching operations that are part of an ore beneficiation plant.

Process Water Use Reduction

Process water use reduction is the decrease in the amount of process water used as an influent to a production process per unit of production. Section V of each of the subcategory supplements discusses water use in detail for each nonferrous metals manufacturing operation. A range of water use values taken from the data collection portfolios is presented for each operation. The range of values indicates that some plants use process water more efficiently than others for the same operation.

Application and Performance. Noncontact cooling water can replace contact cooling water in some applications. The use of noncontact heat exchangers eliminates concentration of dissolved solids by evaporation and minimizes scaling problems. A copper refinery is currently using this method to achieve zero discharge. However, industry-wide conversion to noncontact cooling may not be possible because of a need for extensive retrofitting. Certain molten metals require contact cooling to produce desired surface characteristics. Some plants produce a metal shot by allowing molten metal to flow through a screen into a tank of water, immediately quenching the metal and producing a spherical shot product. Shot, generally cannot be produced without contact cooling water.

Air Cooling of Cast Metal Products

Application and Performance. Air cooling, for some operations, is an alternative to contact cooling water but limited potential except in low tonnage situations. For example, air cooling is not generally used in the production of high tonnage casting for several reasons. The casting line can be inordinately long (or large), a result of an increased number of molds to compensate for the slower cooling of the metal.

Operational Factors. Maintenance costs are generally higher because of the longer conveyor, the added heat load on equipment and lubricants, and the need for added air blowers. Air cooling without these process appurtenances might greatly reduce finished metal production from rates now possible with water cooling.

Conversion to dry air pollution control equipment, discussed further on in this section, is another way to eliminate water use.

Dry Slag Processing and Granulation

Slag from pyrometallurgical processes is a solid waste that must be disposed of or reprocessed. Slag can be prepared for disposal by slag granulation or slag dumping.

Application and Performance. Slag granulation uses a high-velocity water jet to produce a finely divided and evenly sized rock, which can be used as concrete agglomerate or for road surfacing. Slag dumping is the dumping and subsequent solidification of slag, composed almost entirely of insolubles, which can be crushed and sized for such applications as road surfacing. Slag can be reprocessed if the metal content is high enough to be economically recovered. Wet or dry milling, and recovery of metal by melting can be used to process slag with recoverable amounts of metal. Of course, in all slag reuse processes, ultimate disposal of the reprocessed slag must be considered.

Operational Factors. Although slag dumping eliminates the wastewater associated with slag granulation, an additional factor is that large volumes of dust are generated during subsequent crushing operations and dust control systems may be necessary.

Demonstration Status. Four of the seven primary lead smelters currently granulate slag prior to disposal. One of the four plants granulates the slag, mixes the granulated slag in with ore concentrate feed to sintering because the lead content of the slag is high enough to be economically recovered.

Dry Air Pollution Control Devices

Application and Performance. The use of dry air pollution control devices would allow the elimination of waste streams with high pollution potentials. The choice of air pollution control equipment is complicated, and sometimes a wet system is the necessary choice. The important difference between wet and dry devices is that wet devices control gaseous pollutants as well as particulates.

Wet devices may be chosen over dry devices when any of the following factors are found: (1) the particle size is predominantly under 20 microns, (2) flammable particles or gases are to be treated at minimal combustion risk, (3) both vapors and particles are to be removed from the carrier medium, (4) the gases are corrosive and may damage dry air pollution control devices, and (5) the gases are hot and may damage dry air pollution control devices.

Equipment for dry control of air emissions includes cyclones, dry electrostatic precipitators, fabric filters, and afterburners. These devices remove particulate matter, the first three by entrapment and the afterburners by combustion.

Afterburner use is limited to air emissions consisting mostly of combustible particles. Characteristics of the particulate-laden gas which affect the design and use of a device are gas density, temperature, viscosity, flammability, corrosiveness, toxicity, humidity, and dew point. Particulate characteristics which affect the design and use of a device are particle size, shape, density, resistivity, concentration, and other physiochemical properties.

In the primary and secondary aluminum subcategories, melting prior to casting requires wet air pollution control only when chlorine gas is present in the offgases. Dry air pollution control methods with inert gas or salt furnace fluxing have been demonstrated in the category. It is possible to perform all the metal treatment tasks of removing hydrogen, non-metallic inclusions, and undesirable trace elements and meet the most stringent quality requirements without furnace fluxing, using only in-line metal treatment units. To achieve this, the molten aluminum is treated in the transfer system between the furnace and casting units by flowing the metal through a region of very fine, dense, mixed-gas bubbles generated by a spinning rotor or nozzle. No process wastewater is generated in this operation. A schematic diagram depicting the spinning nozzle refining principle is shown in Figure VII-33. Another similar alternate degassing method is to replace the chlorine-rich degassing agent with a mixture of inert gases and a much lower proportion of chlorine. The technique provides adequate degassing while permitting dry scrubbing.

To the extent that nonferrous metals manufacturing processes are designed to limit the volume or severity of air emissions, the volume of scrubber water used for air pollution control also can be reduced. For example, new or replacement furnaces can be designed to minimize emission volumes.

Advantages and Limitations. Proper application of a dry control device can result in particulate removal efficiencies greater than 99 percent by weight for fabric filters, elecrtrostatic precipitators, and afterburners, and up to 95 percent for cyclones.

Common wet air pollution control devices are wet electrostatic precipitators, venturi scrubbers, and packed tower scrubbers. Collection efficiency for gases will depend on the solubility of the contaminant in the scrubbing liquid. Depending on the contaminant removed, collection efficiencies ususally approach 99 percent for particles and gases.

Demonstration Status. Plants in the primary and secondary aluminum, primary zinc, primary lead, secondary copper and secondary silver subcategories all report the use of dry air pollution control devices on furnaces and casting operations.

Good Housekeeping

Good housekeeping and proper equipment maintenance are necessary factors in reducing wastewater loads to treatment systems. Control of accidental spills of oils, process chemicals, and wastewater from washdown and filter cleaning or removal can aid in abating or maintaining the segregation of wastewater streams. Curbed areas should be used to contain or control these wastes.

Leaks in pump casings, process piping, etc., should be minimized to maintain efficient water use. One particular type of leakage which may cause a water pollution problem is the contamination of noncontact cooling water by hydraulic oils, especially if this type of water is discharged without treatment.

Good housekeeping is also important in chemical, solvent, and oil storage areas to preclude a catastrophic failure situation. Storage areas should be isolated from high fire-hazard areas and arranged so that if a fire or explosion occurs, treatment facilities will not be overwhelmed nor excessive groundwater pollution caused by large quantities of chemical-laden fire-protection water.

A conscientiously applied program of water use reduction can be a very effective method of curtailing unnecessary wastewater flows. Judicious use of washdown water and avoidance of unattended running hoses can significantly reduce water use.

Table VII-1

pH CONTROL EFFECT ON METALS REMOVAL

	Day 1		Day 2		Day 3	
	In	Out	In	Out	In	Out
pH Range	2.4-3.4	8.5-8.7	1.0-3.0	5.0-6.0	2.0-5.0	6.5-8.1
(mg/l)						
TSS	39	8	16	19	16	7
Copper	312	0.22	120	5.12	107	0.66
Zinc	250	0.31	32.5	25.0	43.8	0.66

Source: Development Document for Effluent Limitations Guidelines and Standards for the Copper Forming Point Source Category, U.S. EPA, EPA 440/1-82/074b.

Table VII-2

EFFECTIVENESS OF SODIUM HYDROXIDE FOR METALS REMOVAL

	Day 1		Day 2		Day 3	
	In	Out	In	Out	In	Out
pH Range	2.1-2.9	9.0-9.3	2.0-2.4	8.7-9.1	2.0-2.4	8.6-9.1
(mg/l)						
Cr	0.097	0.0	0.057	0.005	0.068	0.005
Cu	0.063	0.018	0.078	0.014	0.053	0.019
Fe	9.24	0.76	15.5	0.92	9.41	0.95
Pb	1.0	0.11	1.36	0.13	1.45	0.11
Mn	0.11	0.06	0.12	0.044	0.11	0.044
Ni	0.077	0.011	0.036	0.009	0.069	0.011
Zn	0.054	0.0	0.12	0.0	0.19	0.037
TSS		13		11		11

Source: Development Document for Effluent Limitations, Guidelines and Standards for the Battery Manufacturing Point Source Category, U.S. EPA, EPA 440/1-82/067b.

Table VII-3

EFFECTIVENESS OF LIME AND SODIUM HYDROXIDE FOR METALS REMOVAL

	Day 1		Day 2		Day 3	
	In	Out	In	Out	In	Out
pH Range	9.2-9.6	8.3-9.8	9.2	7.6-8.1	9.6	7.8-8.2
(mg/l)						
Al	37.3	0.35	38.1	0.35	29.9	0.35
Co	3.92	0.0	4.65	0.0	4.37	0.0
Cu	0.65	0.003	0.63	0.003	0.72	0.003
Fe	137	0.49	110	0.57	208	0.58
Mn	175	0.12	205	0.012	245	0.12
Ni	6.86	0.0	5.84	0.0	5.63	0.0
Se	28.6	0.0	30.2	0.0	27.4	0.0
Ti	143	0.0	125	0.0	115	0.0
Zn	18.5	0.027	16.2	0.044	17.0	0.01
TSS	4,390	9	3,595	13	2,805	13

Source: Development Document for Effluent Limitations Guidelines and Standards for the Porcelain Enameling Point Source Category, U.S. EPA, EPA 440/1-82/072.

Table VII-4

THEORETICAL SOLUBILITIES OF HYDROXIDES AND SULFIDES OF SELECTED METALS IN PURE WATER

	Solubility of Metal Ion, mg/l		
Metal	As Hydroxide	As Carbonate	As Sulfide
Cadmium (Cd++)	2.3×10^{-5}	1.0×10^{-4}	6.7×10^{-10}
Chromium (Cr+++)	8.4×10^{-4}		No precipitate
Cobalt (Co++)	2.2×10^{-1}		1.0×10^{-8}
Copper (Cu++)	2.2×10^{-2}		5.8×10^{-18}
Iron (Fe++)	8.9×10^{-1}		3.4×10^{-5}
Lead (Pb++)	2.1	7.0×10^{-3}	3.8×10^{-9}
Manganese (Mn++)	1.2		2.1×10^{-3}
Mercury (Hg++)	3.9×10^{-4}	3.9×10^{-2}	9.0×10^{-20}
Nickel (Ni++)	6.9×10^{-3}	1.9×10^{-1}	6.9×10^{-8}
Silver (Ag+)	13.3	2.1×10^{-1}	7.4×10^{-12}
Tin (Sn++)	1.1×10^{-4}		3.8×10^{-8}
Zinc (Zn++)	1.1	7.0×10^{-4}	2.3×10^{-7}

Source: *Lange's Handbook of Chemistry*, McGraw-Hill, New York, 1980.

Table VII-5

SAMPLING DATA FROM SULFIDE PRECIPITATION-SEDIMENTATION SYSTEMS

Treatment	Lime, FeS, Polyelectrolyte, Settle, Filter		Lime, FeS, Polyelectrolyte, Settle, Filter		NaOH, Ferric Chloride, Na_2S, Clarify (1 Stage)	
	In	Out	In	Out	In	Out
pH	5.0-6.8	8-9	7.7	7.38		
(mg/1)						
Cr+6	25.6	<0.014	0.022	<0.020	11.45	<.005
Cr	32.3	<0.04	2.4	<0.1	18.35	<.005
Cu	--	--	--	--	0.029	0.003
Fe	0.52	0.10	108	0.6	--	--
Ni	--	--	0.68	<0.1	--	--
Zn	39.5	<0.07	33.9	<0.1	0.060	0.009

Sources: Summary Report, Control and Treatment Technology for the Metal Finishing Industry: Sulfide Precipitation, U.S. EPA, EPA No. 625/8/80-003, 1979.

Industry Finishing, Vol. 35, No. 11, November, 1979.

Electroplating sampling data from plant 27045.

Table VII-6

SULFIDE PRECIPITATION-SEDIMENTATION PERFORMANCE

Parameter	Treated Effluent (mg/l)
Cd	0.01
Cr (Total)	0.05
Cu	0.05
Pb	0.01
Hg	0.03
Ni	0.05
Ag	0.05
Zn	0.01

Sources: Summary Report, Control and Treatment Technology for the Metal Finishing Industry: Sulfide Precipitation, U.S. EPA, EPA No. 625/8/80-003, 1979.

Addendum to Development Document for Effluent Limitations Guidelines and New Source Performance Standards, Major Inorganic Products Segment of Inorganics Point Source Category, U.S. EPA, EPA Contract No. EPA/68-01-3281 (Task 7), June, 1978.

Table VII-7

FERRITE CO-PRECIPITATION PERFORMANCE

Metal	Influent (mg/l)	Effluent (mg/l)
Mercury	7.4	0.001
Cadmium	240	0.008
Copper	10	0.010
Zinc	18	0.016
Chromium	10	<0.010
Manganese	12	0.007
Nickel	1,000	0.200
Iron	600	0.06
Bismuth	240	0.100
Lead	475	0.010

Source: Sources and Treatment of Wastewater in the Nonferrous Metals Industry, U.S. EPA, EPA No. 600/2-80-074, 1980.

Table VII-8

CONCENTRATION OF TOTAL CYANIDE (mg/1)

Plant	Method	In	Out
1057	$FeSO_4$	2.57	0.024
		2.42	0.015
		3.28	0.032
33056	$FeSO_4$	0.14	0.09
		0.16	0.09
12052	$ZnSO_4$	0.46	0.14
		0.12	0.06
Mean			0.07

Source: Development Document for Proposed Effluent Limitations Guidelines and Standards for the Coiling Coating Point Source Category, U.S. EPA, EPA 440/1-81-071b, November, 1982.

Table VII-9

MULTIMEDIA FILTER PERFORMANCE

Plant ID #	TSS Effluent Concentration, mg/l
06097	0.0, 0.0, 0.5
13924	1.8, 2.2, 5.6, 4.0, 4.0, 3.0, 2.2, 2.8 3.0, 2.0, 5.6, 3.6, 2.4, 3.4
18538	1.0
30172	1.4, 7.0, 1.0
36048	2.1, 2.6, 1.5
Mean	2.61

Source: Development Document for Effluent Limitations, Guidelines and Standards for the Battery Manufacturing Point Source Category, U.S. EPA, EPA 440/1-82/067b.

Development Document for Effluent Limitations Guidelines and Standards for the Porcelain Enameling Point Source Category, U.S. EPA, EPA 440/1-82/072.

Table VII-10

PERFORMANCE OF SELECTED SETTLING SYSTEMS

Plant ID	Settling Device	SUSPENDED SOLIDS CONCENTRATION (mg/l)					
		Day 1		Day 2		Day 3	
		In	Out	In	Out	In	Out
01057	Lagoon	54	6	56	6	50	5
09025	Clarifier + Settling Ponds	1,100	9	1,900	12	1,620	5
11058	Clarifier	451	17	--	--	--	--
12075	Settling Pond	284	6	242	10	502	14
19019	Settling Tank	170	1	50	1	--	--
33617	Clarifier & Lagoon	--	--	1,662	16	1,298	4
40063	Clarifier	4,390	9	3,595	12	2,805	13
44062	Clarifier	182	13	118	14	174	23
46050	Settling Tank	295	10	42	10	153	8

Source: Development Document for Effluent Limitations Guidelines and Standards for the Porcelain Enameling Point Source Category, U.S. EPA, EPA 440/1-82/072.

Table VII-11

SKIMMING PERFORMANCE

Plant	Skimmer Type	Oil & Grease (mg/l) In	Oil & Grease (mg/l) Out
06058	API	224,669	17.9
06058	Belt	19.4	8.3

Source: Development Document for Effluent Limitations Guidelines and Standards for the Copper Forming Point Source Category, U.S. EPA, EPA 440/1-82/074b.

Table VII-12

COMBINED METALS DATA EFFLUENT VALUES (mg/l)

	Mean	One-Day Max.	10-Day Avg. Max.	30-Day Avg. Max.
Cd	0.079	0.32	0.15	0.13
Cr	0.08	0.42	0.17	0.12
Cu	0.58	1.90	1.00	0.73
Pb	0.12	0.15	0.13	0.12
Ni	0.57	1.41	1.00	0.75
Zn	0.30	1.33	0.56	0.41
Fe	0.41	1.23	0.63	0.51
Mn	0.21	0.43	0.34	0.27
TSS	12.0	41.0	20.0	15.5

Table VII-13

L&S PERFORMANCE
ADDITIONAL POLLUTANTS

Pollutant	Average Performance (mg/1)
Sb	0.7
As	0.51
Be	0.30
Hg	0.06
Se	0.30
Ag	0.10
Tl	0.50
Al	1.11
Co	0.05
F	14.5

Table VII-14

COMBINED METALS DATA SET - UNTREATED WASTEWATER

Pollutant	Min. Conc. (mg/l)	Max. Conc. (mg/l)
Cd	<0.1	3.83
Cr	<0.1	116
Cu	<0.1	108
Pb	<0.1	29.2
Ni	<0.1	27.5
Zn	<0.1	337.
Fe	<0.1	263
Mn	<0.1	5.98
TSS	4.6	4,390

Table VII-15

MAXIMUM POLLUTANT LEVEL IN UNTREATED WASTEWATER ADDITIONAL POLLUTANTS (mg/l)

Pollutant	As & Se	Be	Ag	F
As	4.2	--	--	--
Be	--	10.24	--	--
Cd	<0.1	--	<0.1	<0.1
Cr	0.18	8.60	0.23	22.8
Cu	33.2	1.24	110.5	2.2
Pb	6.5	0.35	11.4	5.35
Ni	--	--	100	0.69
Ag	--	--	4.7	--
Zn	3.62	0.12	1,512	<0.1
F	--	--	--	760
Fe	--	646	--	--
O&G	16.9	--	16	2.8
TSS	352	796	587.8	5.6

Table VII-16

PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE
PLANT A

Parameters	No. Points	Range mg/l	Mean ± Std. Dev.	Mean + 2 Std. Dev.
For 1979-Treated Wastewater				
Cr	47	0.015 - 0.13	0.045 ± 0.029	0.10
Cu	12	0.01 - 0.03	0.019 ± 0.006	0.03
Ni	47	0.08 - 0.64	0.22 ± 0.13	0.48
Zn	47	0.08 - 0.53	0.17 ± 0.09	0.35
Fe				
For 1978-Treated Wastewater				
Cr	47	0.01 - 0.07	0.06 ± 0.10	0.26
Cu	28	0.005 - 0.055	0.016 ± 0.010	0.04
Ni	47	0.10 - 0.92	0.20 ± 0.14	0.48
Zn	47	0.08 - 2.35	0.23 ± 0.34	0.91
Fe	21	0.26 - 1.1	0.49 ± 0.18	0.85
Raw Waste				
Cr	5	32.0 - 72.0		
Cu	5	0.08 - 0.45		
Ni	5	1.65 - 20.0		
Zn	5	33.2 - 32.0		
Fe	5	10.0 - 95.0		

Table VII-17

PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE
PLANT B

Parameters	No. Points	Range mg/l	Mean ± Std. Dev.	Mean + 2 Std. Dev.
For 1979-Treated Wastewater				
Cr	175	0.0 - 0.40	0.068 ± 0.075	0.22
Cu	176	0.0 - 0.22	0.024 ± 0.021	0.07
Ni	175	0.01 - 1.49	0.219 ± 0.234	0.69
Zn	175	0.01 - 0.66	0.054 ± 0.064	0.18
Fe	174	0.01 - 2.40	0.303 ± 0.398	1.10
TSS	2			
		1.00 - 1.00		
For 1978-Treated Wastewater				
Cr	144	0.0 - 0.70	0.059 ± 0.088	0.24
Cu	143	0.0 - 0.23	0.017 ± 0.020	0.06
Ni	143	0.0 - 1.03	0.147 ± 0.142	0.43
Zn	131	0.0 - 0.24	0.037 ± 0.034	0.11
Fe	144	0.0 - 1.76	0.200 ± 0.223	0.47
Total 1974-1979-Treated Wastewater				
Cr	1,288	0.0 - 0.56	0.038 ± 0.055	0.15
Cu	1,290	0.0 - 0.23	0.011 ± 0.016	0.04
Ni	1,287	0.0 - 1.88	0.184 ± 0.211	0.60
Zn	1,273	0.0 - 0.66	0.035 ± 0.045	0.13
Fe	1,287	0.0 - 3.15	0.402 ± 0.509	1.42
Raw Waste				
Cr	3	2.80 - 9.15	5.90	
Cu	3	0.09 - 0.27	0.17	
Ni	3	1.61 - 4.89	3.33	
Zn	2	2.35 - 3.39		
Fe	3	3.13 - 35.9	22.4	
TSS	2	177 - 446		

Table VII-18

PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE PLANT C

Parameters	No. Points	Range mg/l	Mean ± Std. Dev.	Mean + 2 Std. Dev.
For Treated Wastewater				
Cd	103	0.010 - 0.500	0.049 ± 0.049	0.147
Zn	103	0.039 - 0.899	0.290 ± 0.131	0.552
TSS	103	0.100 - 5.00	1.244 ± 1.043	3.33
pH	103	7.1 - 7.9	9.2*	
For UnTreated Wastewater				
Cd	103	0.039 - 2.319	0.542 ± 0.381	1.304
Zn	103	0.949 - 29.8	11.009 ± 6.933	24.956
Fe	3	0.107 - 0.46	0.255	
TSS	103	0.80 - 19.6	5.616 ± 2.896	11.408
pH	103	6.8 - 8.2	7.6*	

---

*pH value is median of 103 values.

Table VII-19

SUMMARY OF TREATMENT EFFECTIVENESS (mg/1)

Pollutant Parameter	L&S Technology System				LS&F Technology System			
	Mean	One-Day Max.	10-Day Avg.	30-Day Avg.	Mean	One-Day Max.	10-Day Avg.	30-Day Avg.
114 Sb	0.70	2.87	1.27	1.13	0.034	0.14	0.06	0.06
115 As	0.51	2.09	0.86	0.83	0.34	1.39	0.57	0.55
117 Be	0.30	1.23	0.51	0.49	0.20	0.82	0.34	0.32
118 Cd	0.079	0.32	0.15	0.13	0.049	0.20	0.08	0.08
119 Cr	0.080	0.42	0.17	0.12	0.07	0.37	0.15	0.10
120 Cu	0.58	1.90	1.00	0.73	0.39	1.28	0.61	0.49
121 CN	0.07	0.29	0.12	0.11	0.047	0.20	0.08	0.08
122 Pb	0.12	0.15	0.13	0.12	0.08	0.10	0.09	0.08
123 Hg	0.06	0.25	0.10	0.10	0.036	0.15	0.06	0.06
124 Ni	0.57	1.41	1.00	0.75	0.22	0.55	0.37	0.29
125 Se	0.3	1.23	0.55	0.49	0.007	0.03	0.01	0.01
126 Ag	0.1	0.41	0.17	0.16	0.07	0.29	0.12	0.10
127 Th	0.50	2.05	0.84	0.81	0.34	1.40	0.57	0.55
128 Zn	0.30	1.33	0.56	0.41	0.23	1.02	0.42	0.31
Al	1.11	4.55	1.86	1.80	0.74	3.03	1.24	1.20
Co	0.05	0.21	0.09	0.08	0.05	0.21	0.09	0.08
F	14.5	59.5	26.4	23.5	9.46	38.8	15.8	15.3
Fe	0.41	1.23	0.63	0.51	0.28	1.23	0.63	0.51
Mn	0.21	0.43	0.34	0.27	0.14	0.30	0.23	0.19
P	4.08	16.7	6.83	6.60	2.72	11.2	4.6	4.4
O&G		20.0	12.0	10.0		10.0	10.0	10.0
TSS	12.0	41.0	20.0	15.5	2.6	15.0	12.0	10.0

Table VII-20

ION EXCHANGE PERFORMANCE
(All Values mg/l)

Parameter	Plant A Prior to Purification	 After Purification	Plant B Prior to Purification	 After Purification
Al	5.6	0.20	--	--
Cd	5.7	0.00	--	--
Cr+3	3.1	0.01	--	--
Cr+6	7.1	0.01	--	--
Cu	4.5	0.09	43.0	0.10
CN	9.8	0.04	3.40	0.09
Au	--	--	2.30	0.10
Fe	7.4	0.01	--	--
Pb	--	--	1.70	0.01
Mn	4.4	0.00	--	--
Ni	6.2	0.00	1.60	0.01
Ag	1.5	0.00	9.10	0.01
SO_4	--	--	210.00	2.00
Sn	1.7	0.00	1.10	0.10
Zn	14.8	0.40	--	--

Table VII-21

PEAT ADSORPTION PERFORMANCE

Pollutant	Influent (mg/l)	Effluent (mg/l)
Cr^{+6}	35,000	0.04
Cu	250	0.24
CN	36.0	0.7
Pb	20.0	0.025
Hg	1.0	0.02
Ni	2.5	0.07
Ag	1.0	0.05
Sb	2.5	0.9
Zn	1.5	0.25

Table VII-22

MEMBRANE FILTRATION SYSTEM EFFLUENT

Specific Metal	Manufacturer's Guarantee	Plant 19066		Plant 31022		Predicted Performance
		In	Out	In	Out	
Al	0.5	--	--	--	--	--
Cr, (+6)	0.02	0.46	0.01	5.25	<0.005	--
Cr (T)	0.03	4.13	0.018	98.4	0.057	0.05
Cu	0.1	18.8	0.043	8.00	0.222	0.20
Fe	0.1	288	0.3	21.1	0.263	0.30
Pb	0.05	0.652	0.01	0.288	0.01	0.05
CN	0.02	<0.005	<0.005	<0.005	<0.005	0.02
Ni	0.1	9.56	0.017	194	0.352	0.40
Zn	0.1	2.09	0.046	5.00	0.051	0.10
TSS	--	632	0.1	13.0	8.0	1.0

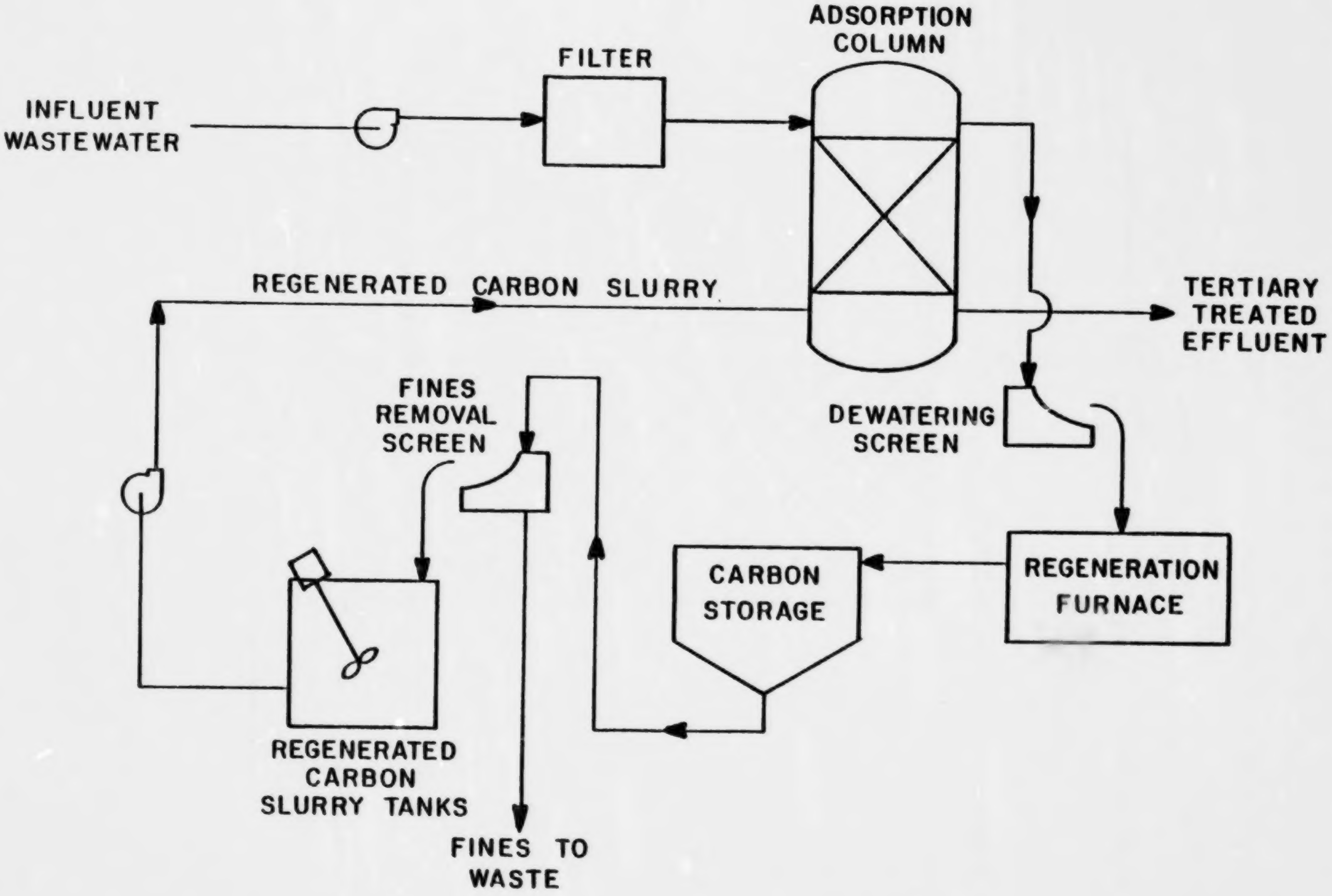

INFLUENT WASTEWATER
FILTER
ADSORPTION COLUMN
REGENERATED CARBON SLURRY
TERTIARY TREATED EFFLUENT
FINES REMOVAL SCREEN
DEWATERING SCREEN
CARBON STORAGE
REGENERATION FURNACE
REGENERATED CARBON SLURRY TANKS
FINES TO WASTE

Figure VII-1

FLOW DIAGRAM OF ACTIVATED CARBON ADSORPTION WITH REGENERATION

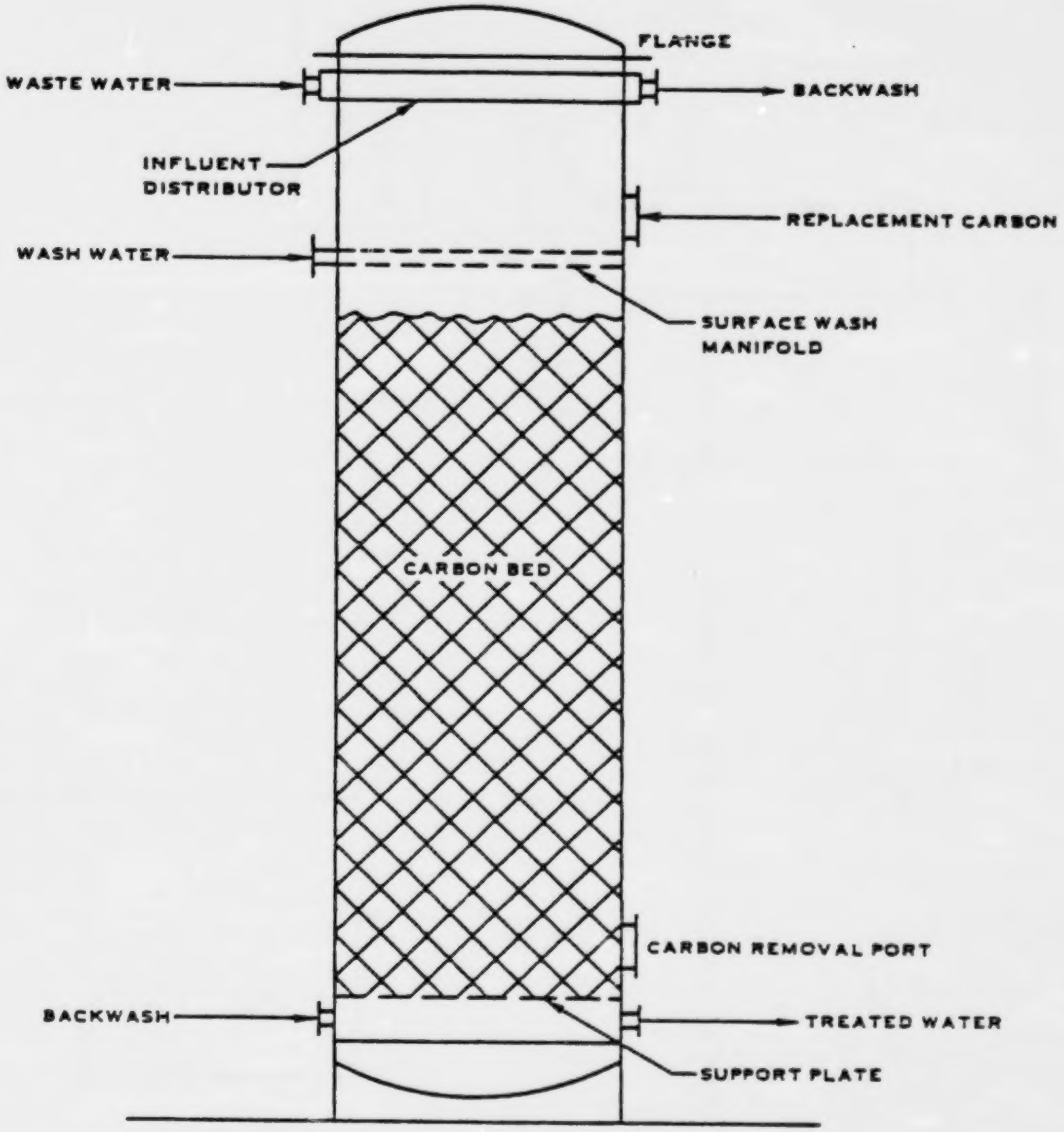

FLANGE
WASTE WATER
BACKWASH
INFLUENT DISTRIBUTOR
REPLACEMENT CARBON
WASH WATER
SURFACE WASH MANIFOLD
CARBON BED
CARBON REMOVAL PORT
BACKWASH
TREATED WATER
SUPPORT PLATE

Figure VII-2

ACTIVATED CARBON ADSORPTION COLUMN

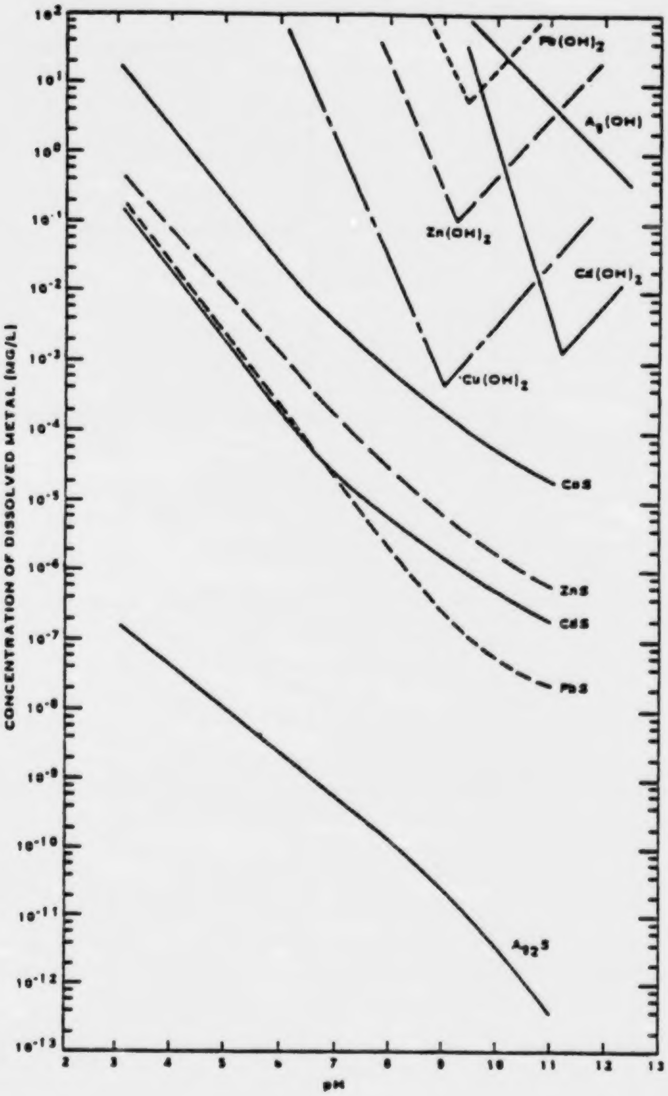


Figure VII-3

COMPARATIVE SOLUBILITIES OF METAL HYDROXIDES
AND SULFIDE AS A FUNCTION OF pH

Source: Development Document for the Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Zinc Segment of the Nonferrous Metals Manufacturing Point Source Category. EPA 440/1-74-033, November, 1974.

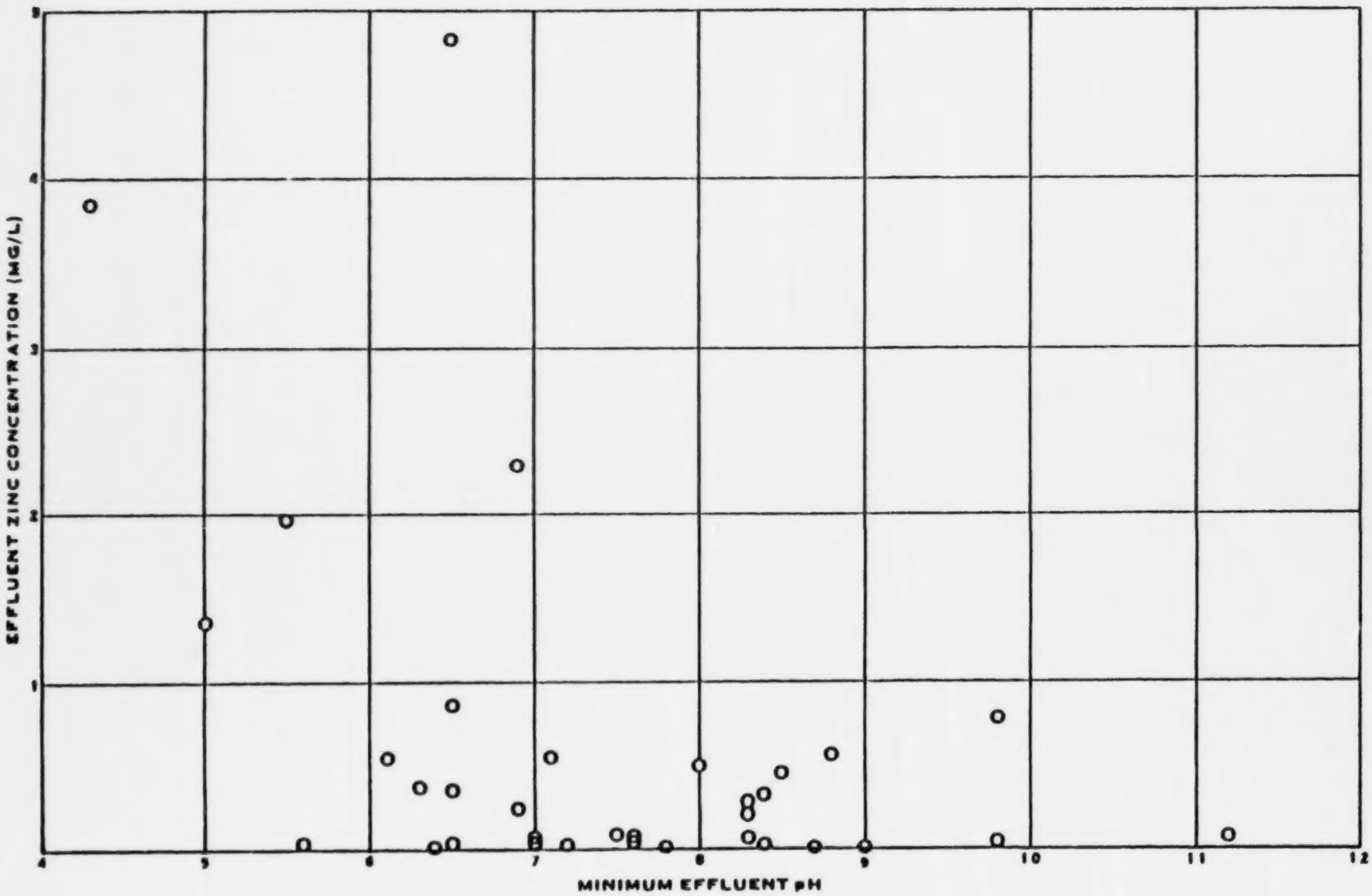


Figure VII-4

EFFLUENT ZINC CONCENTRATION VS. MINIMUM EFFLUENT pH

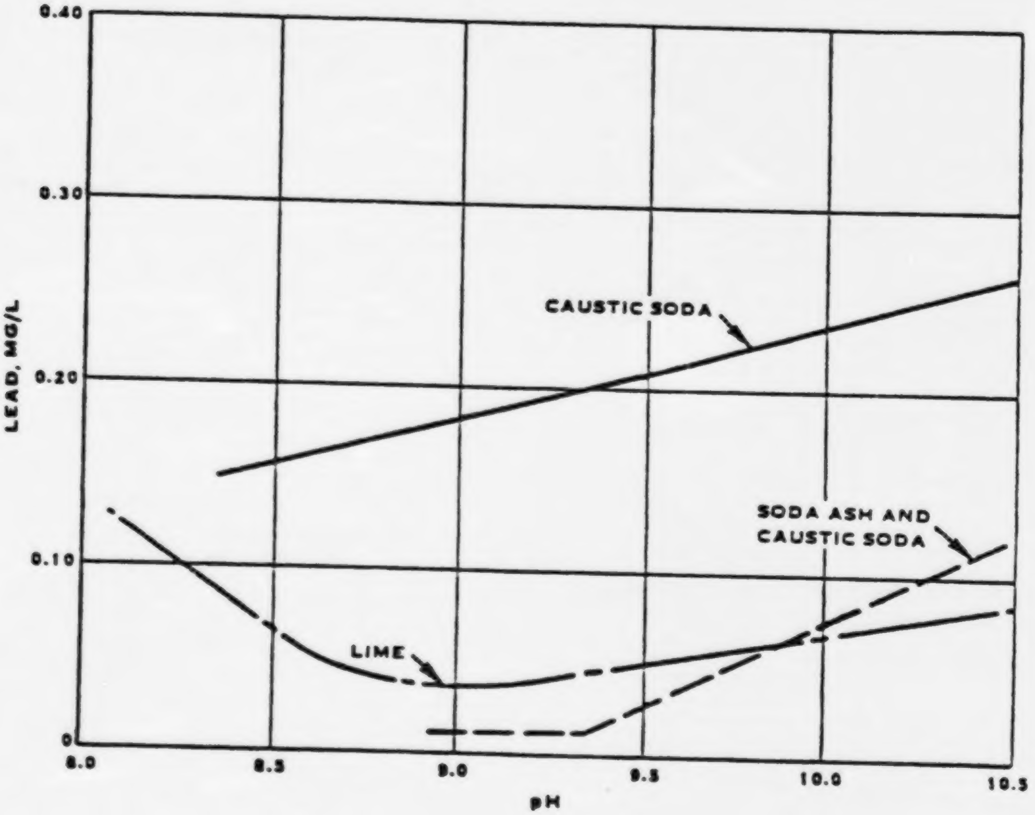
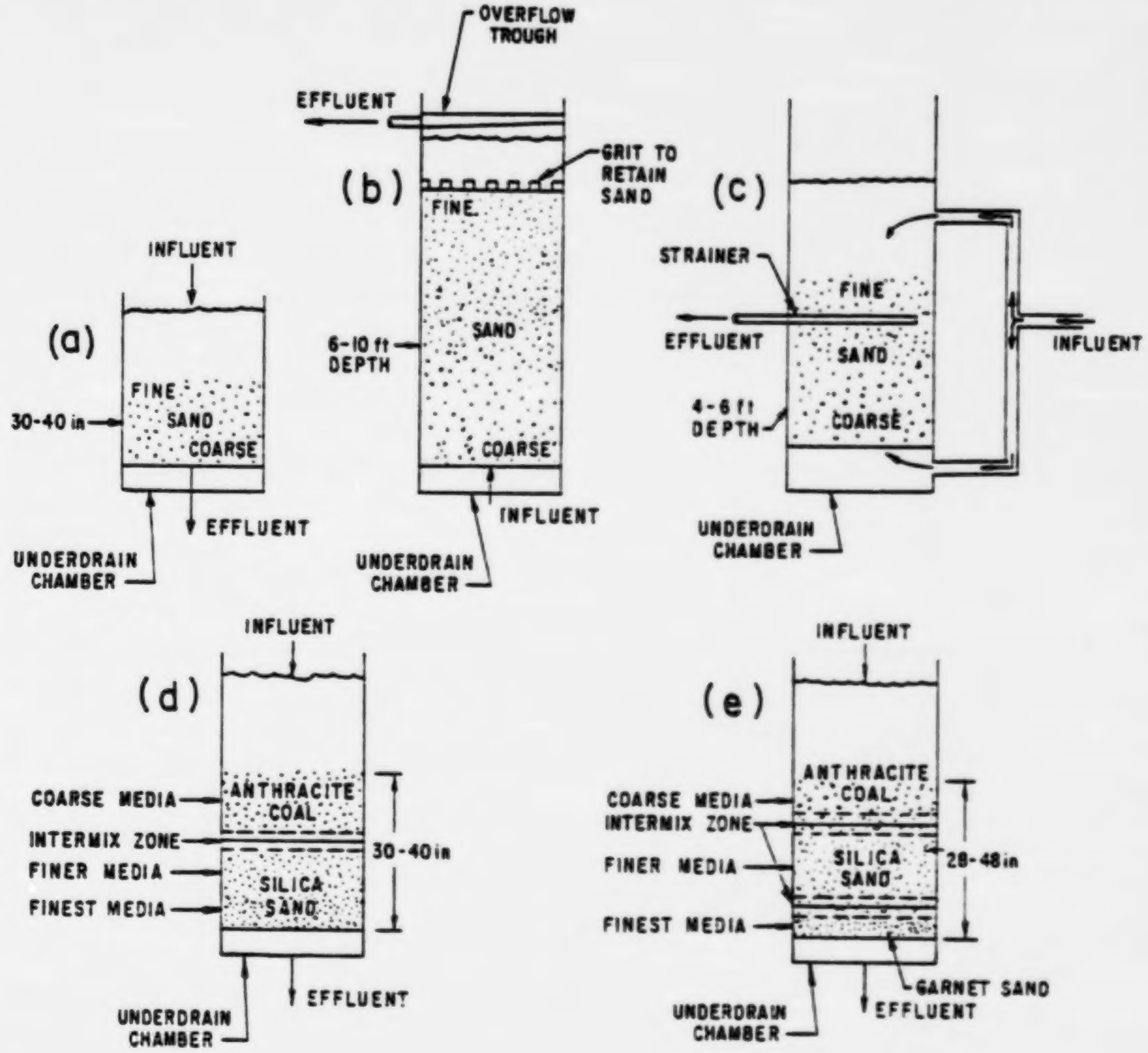


Figure VII-5
LEAD SOLUBILITY IN THREE ALKALIES

Source: Lanovette, Kenneth, "Heavy Metals Removal," Chemical Engineering/Deskbook Issue, October 17, 1977.


OVERFLOW TROUGH
EFFLUENT
GRIT TO RETAIN SAND
(b)
FINE
SAND
6-10 ft DEPTH
COARSE
INFLUENT
UNDERDRAIN CHAMBER
(c)
STRAINER
FINE
SAND
EFFLUENT
INFLUENT
4-6 ft DEPTH
COARSE
UNDERDRAIN CHAMBER
INFLUENT
(a)
FINE
SAND
COARSE
30-40 in
EFFLUENT
UNDERDRAIN CHAMBER
INFLUENT
(d)
COARSE MEDIA
ANTHRACITE COAL
INTERMIX ZONE
FINER MEDIA
SILICA SAND
FINEST MEDIA
30-40 in
UNDERDRAIN CHAMBER
EFFLUENT
INFLUENT
(e)
ANTHRACITE COAL
COARSE MEDIA
INTERMIX ZONE
FINER MEDIA
SILICA SAND
28-48 in
FINEST MEDIA
GARNET SAND
EFFLUENT
UNDERDRAIN CHAMBER

(a) Single-Media Conventional Filter
(b) Single-Media Upflow Filter.
(c) Single-Media Biflow Filter
(d) Dual-Media Filter.
(e) Mixed-Media (Triple-Media) Filter.

Figure VII-6

FILTER CONFIGURATIONS

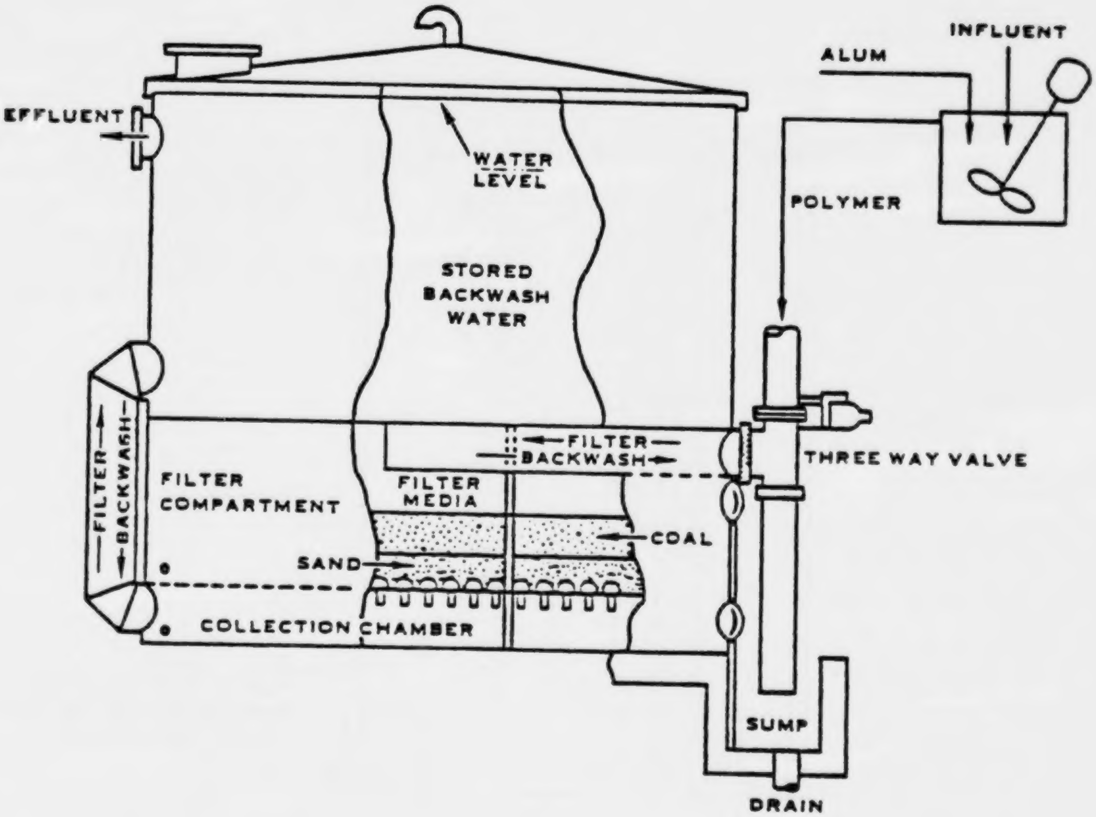

INFLUENT
ALUM
EFFLUENT
WATER LEVEL
POLYMER
STORED BACKWASH WATER
FILTER
BACKWASH
FILTER
BACKWASH
THREE WAY VALVE
FILTER COMPARTMENT
FILTER MEDIA
COAL
SAND
COLLECTION CHAMBER
SUMP
DRAIN

Figure VII-7

GRANULAR BED FILTRATION

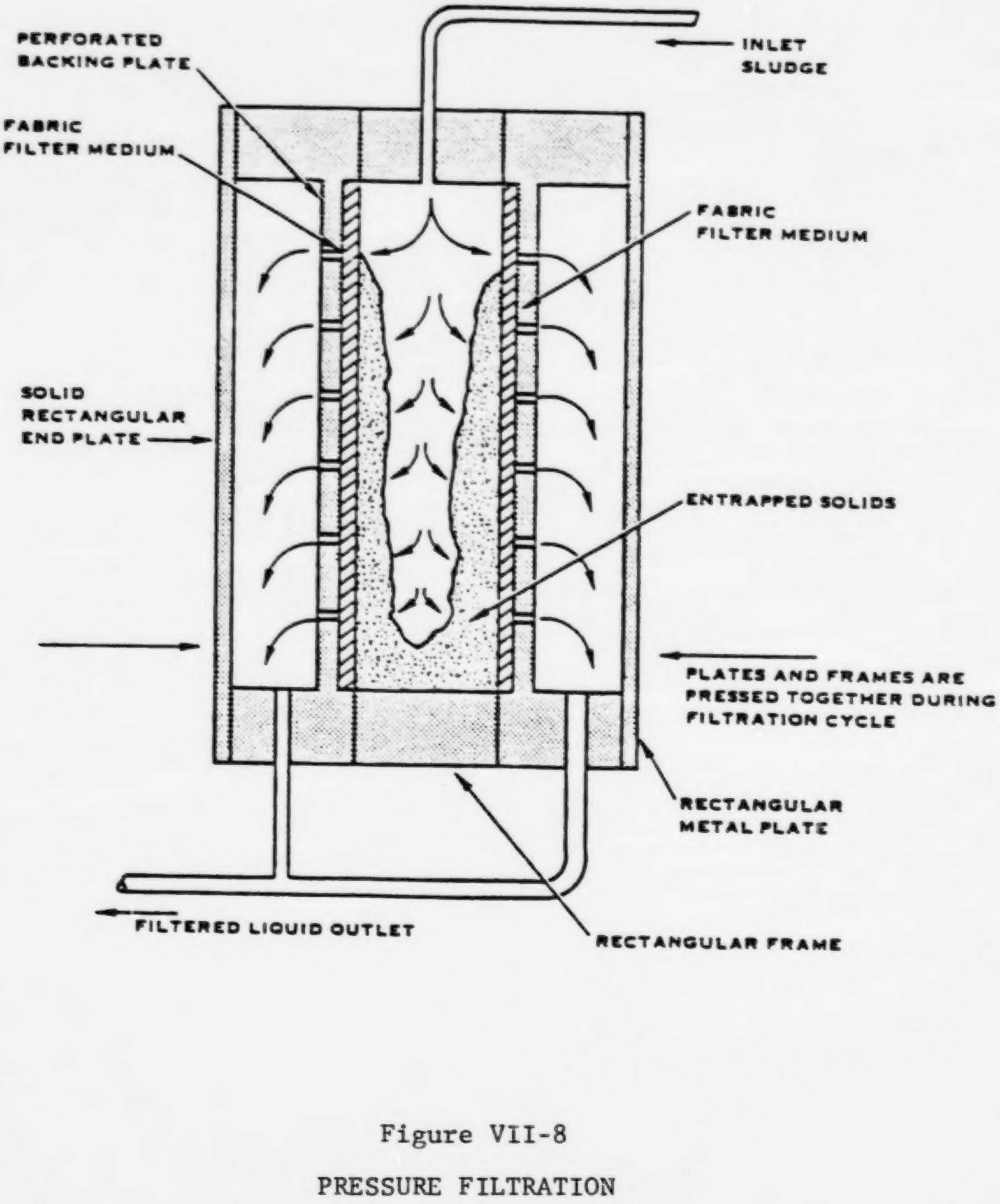
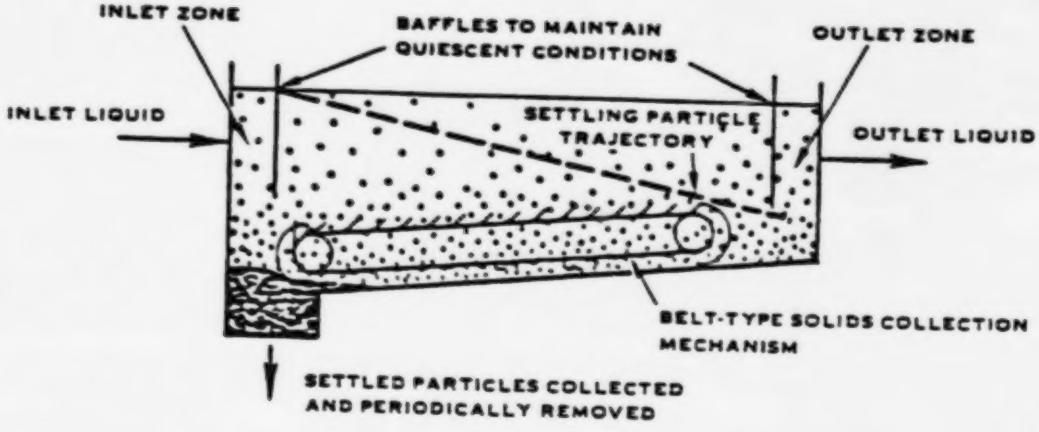

PERFORATED BACKING PLATE
INLET SLUDGE
FABRIC FILTER MEDIUM
FABRIC FILTER MEDIUM
SOLID RECTANGULAR END PLATE
ENTRAPPED SOLIDS
PLATES AND FRAMES ARE PRESSED TOGETHER DURING FILTRATION CYCLE
RECTANGULAR METAL PLATE
FILTERED LIQUID OUTLET
RECTANGULAR FRAME

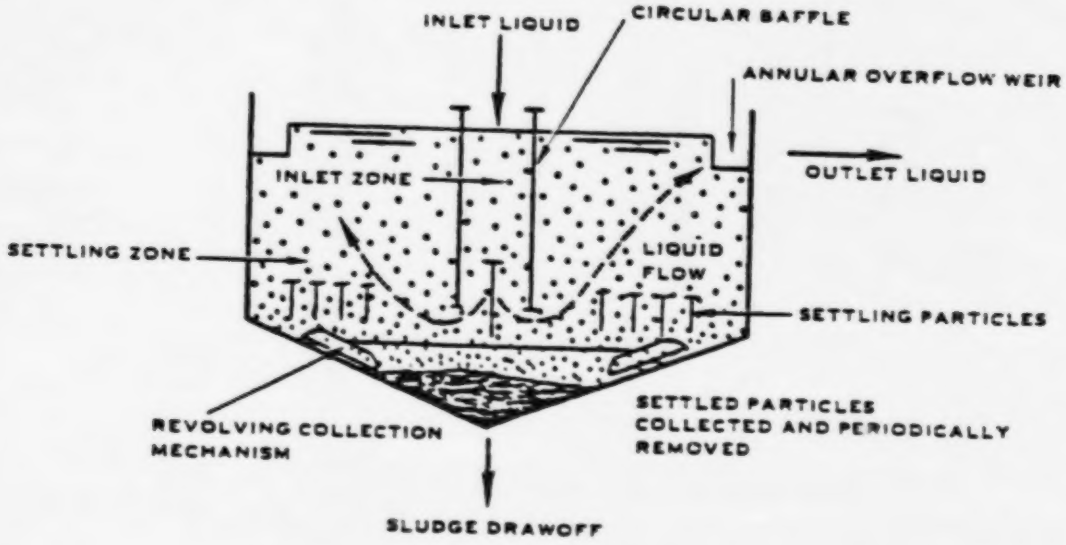
Figure VII-8

PRESSURE FILTRATION



SEDIMENTATION BASIN

INLET ZONE
BAFFLES TO MAINTAIN QUIESCENT CONDITIONS
OUTLET ZONE
INLET LIQUID
SETTLING PARTICLE TRAJECTORY
OUTLET LIQUID
BELT-TYPE SOLIDS COLLECTION MECHANISM
SETTLED PARTICLES COLLECTED AND PERIODICALLY REMOVED



CIRCULAR CLARIFIER

INLET LIQUID
CIRCULAR BAFFLE
ANNULAR OVERFLOW WEIR
INLET ZONE
OUTLET LIQUID
SETTLING ZONE
LIQUID FLOW
SETTLING PARTICLES
REVOLVING COLLECTION MECHANISM
SETTLED PARTICLES COLLECTED AND PERIODICALLY REMOVED
SLUDGE DRAWOFF

Figure VII-9

REPRESENTATIVE TYPES OF SEDIMENTATION

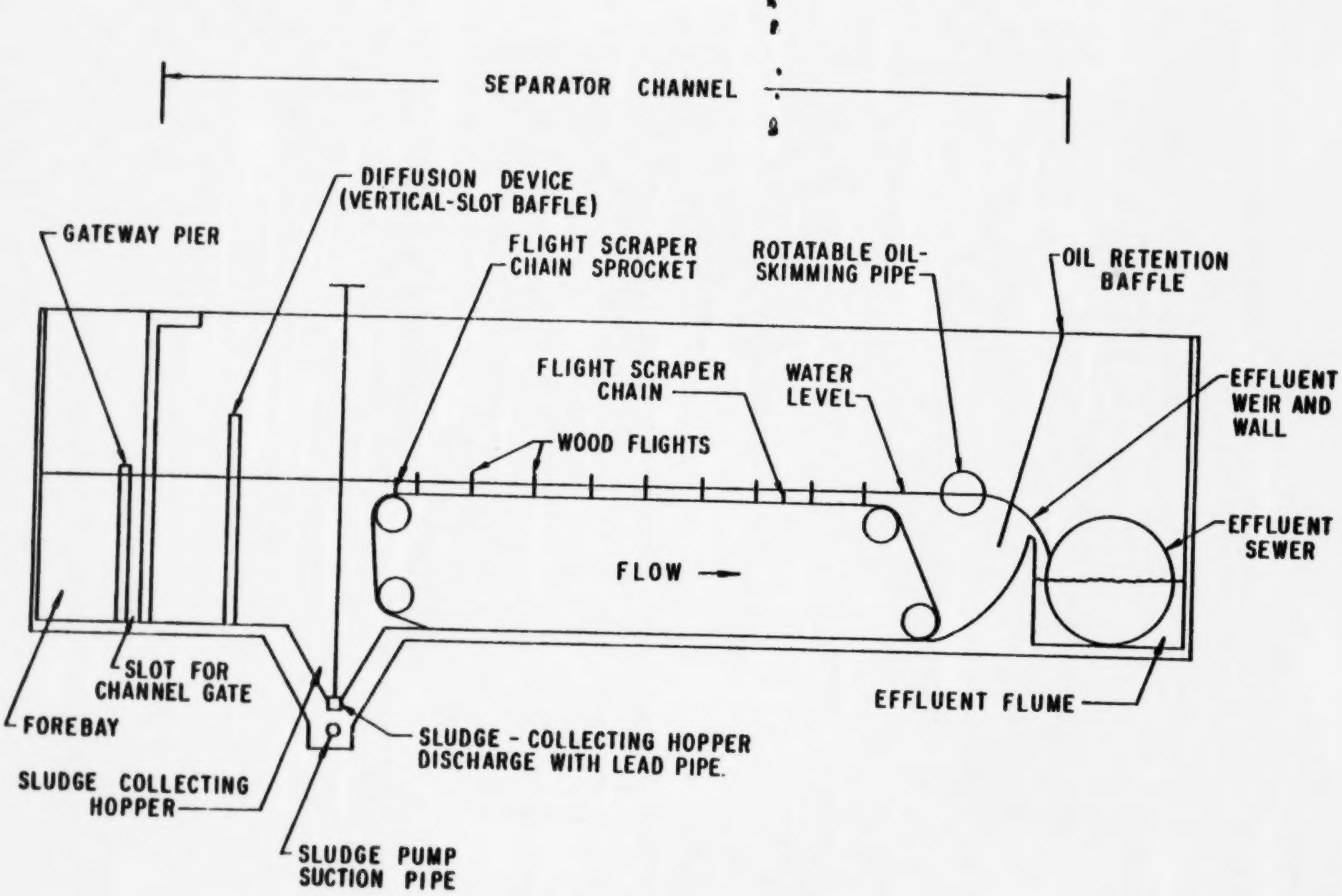
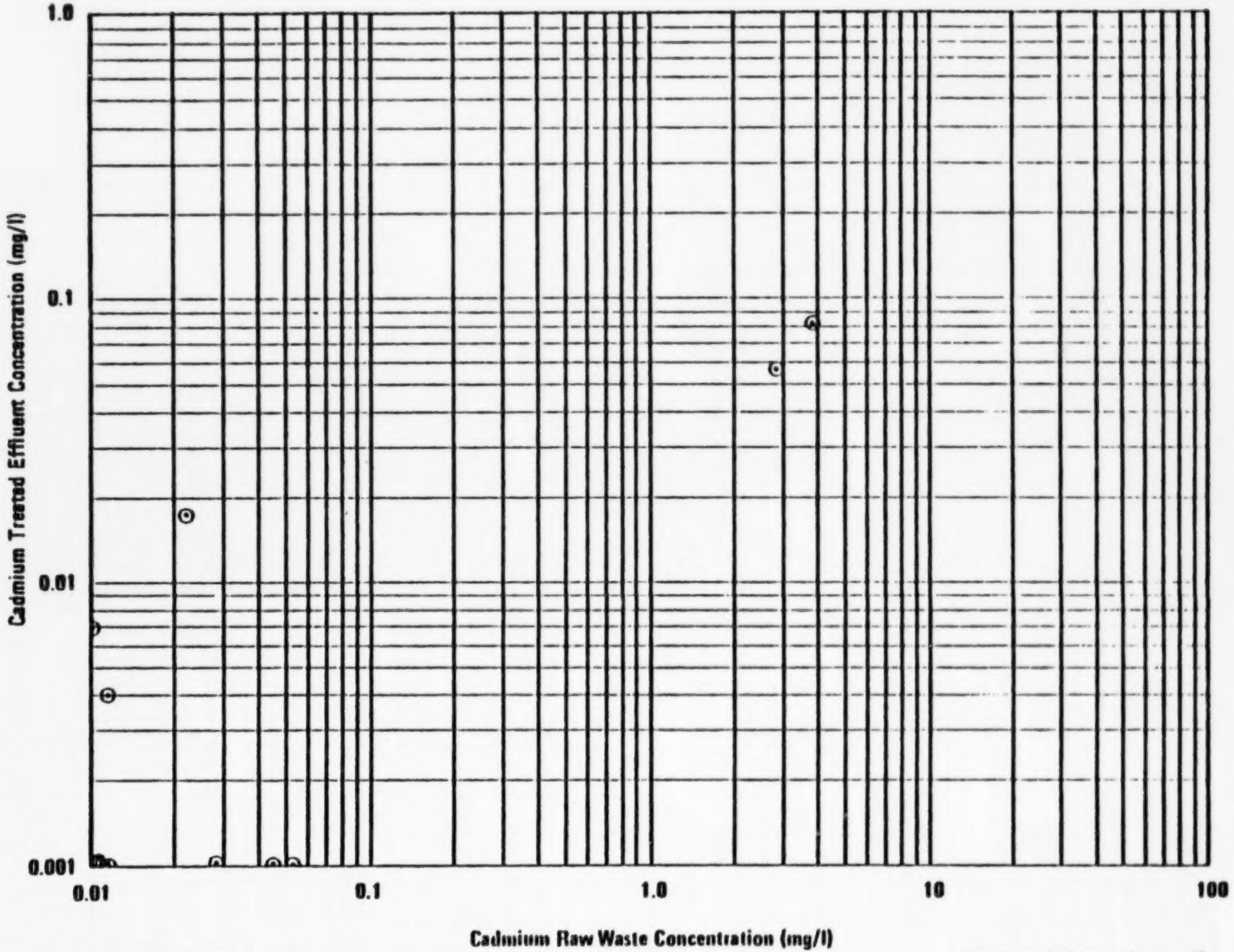

SEPARATOR CHANNEL
DIFFUSION DEVICE (VERTICAL-SLOT BAFFLE)
GATEWAY PIER
FLIGHT SCRAPER CHAIN SPROCKET
ROTATABLE OIL-SKIMMING PIPE
OIL RETENTION BAFFLE
FLIGHT SCRAPER CHAIN
WATER LEVEL
EFFLUENT WEIR AND WALL
WOOD FLIGHTS
EFFLUENT SEWER
FLOW
SLOT FOR CHANNEL GATE
FOREBAY
EFFLUENT FLUME
SLUDGE - COLLECTING HOPPER DISCHARGE WITH LEAD PIPE.
SLUDGE COLLECTING HOPPER
SLUDGE PUMP SUCTION PIPE

Figure VII-10

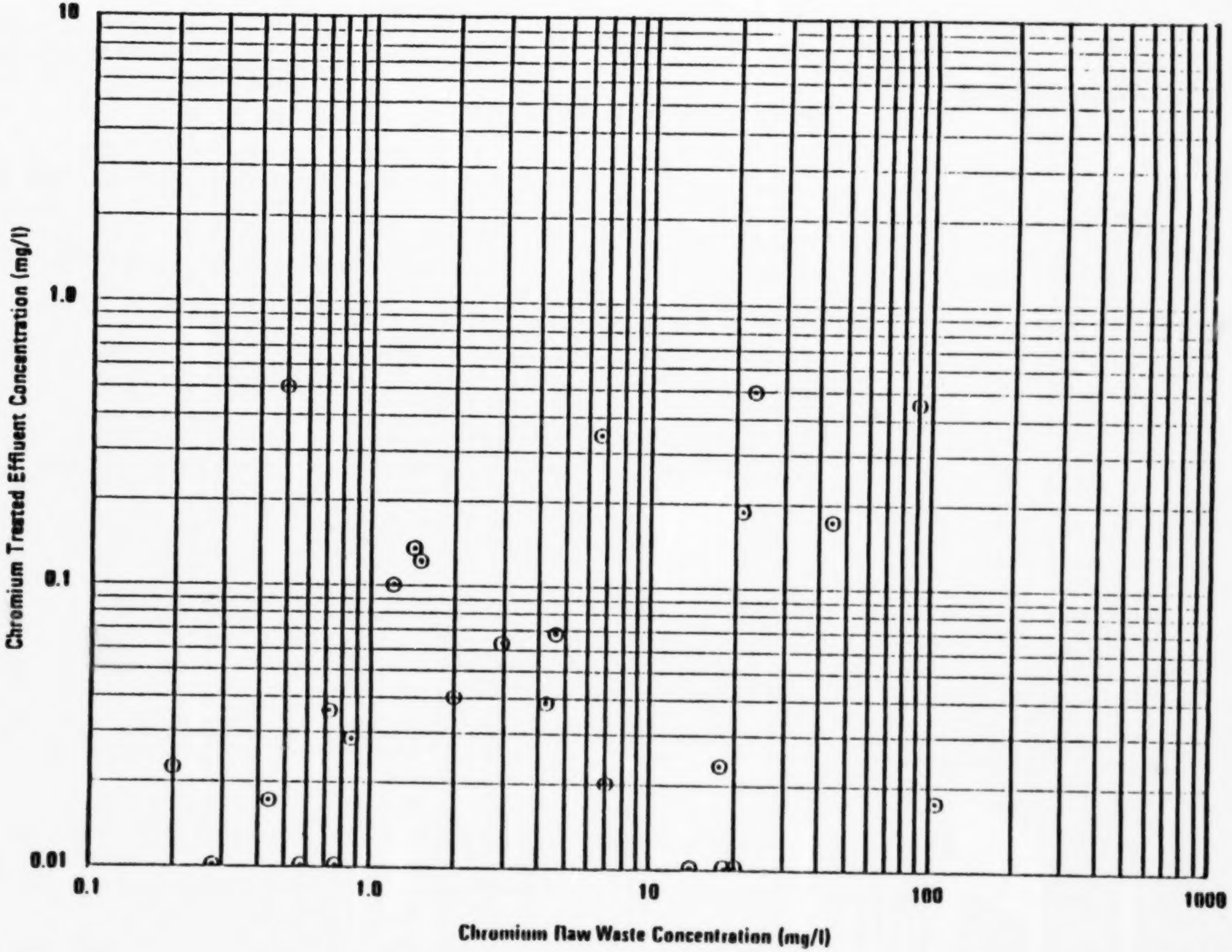
GRAVITY OIL/WATER SEPARATOR



Data points with a raw waste concentration less than 0.1 mg/l were not included in treatment effectiveness calculations.

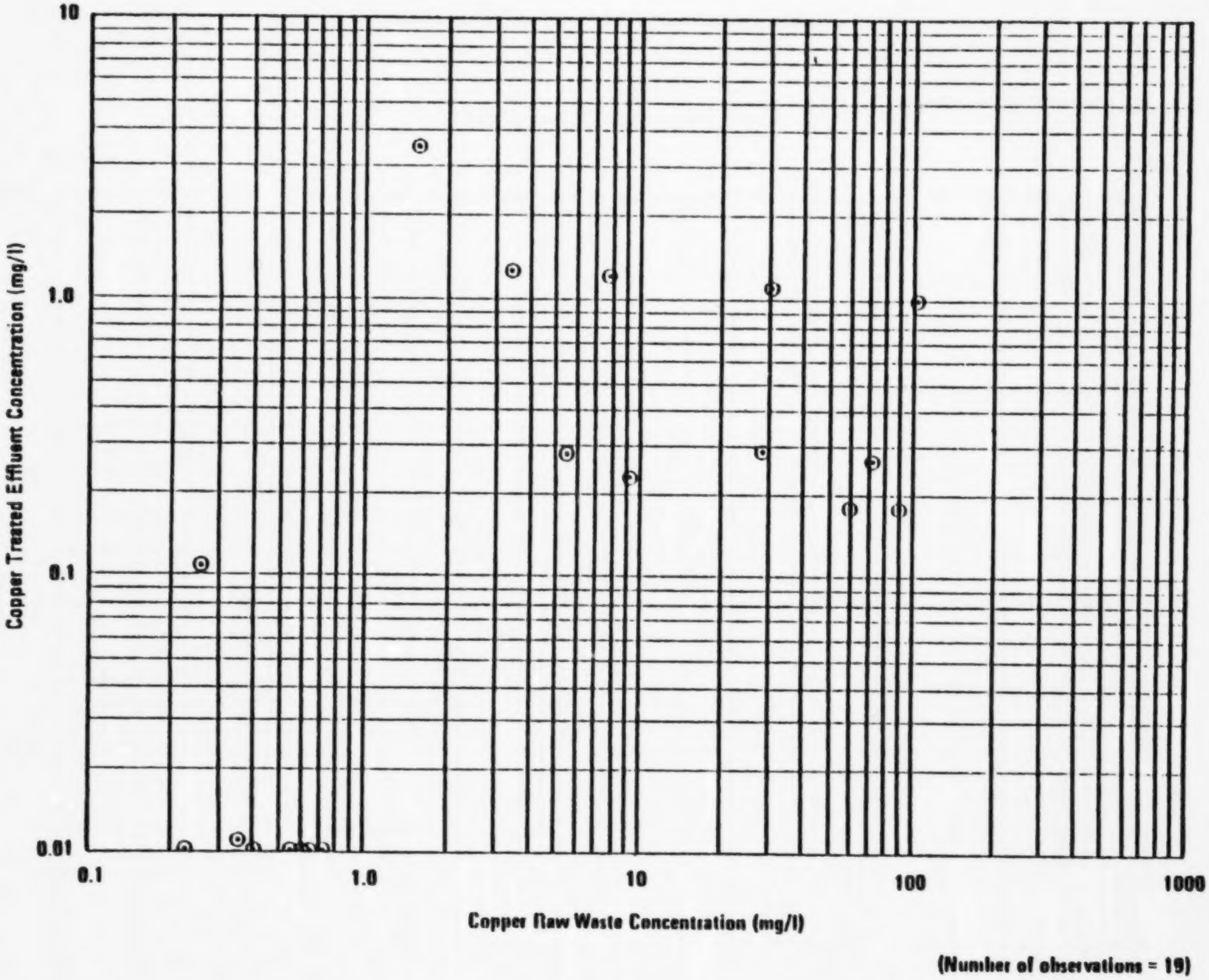
(Number of observations = 2)

FIGURE VII – 11
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
CADMIUM



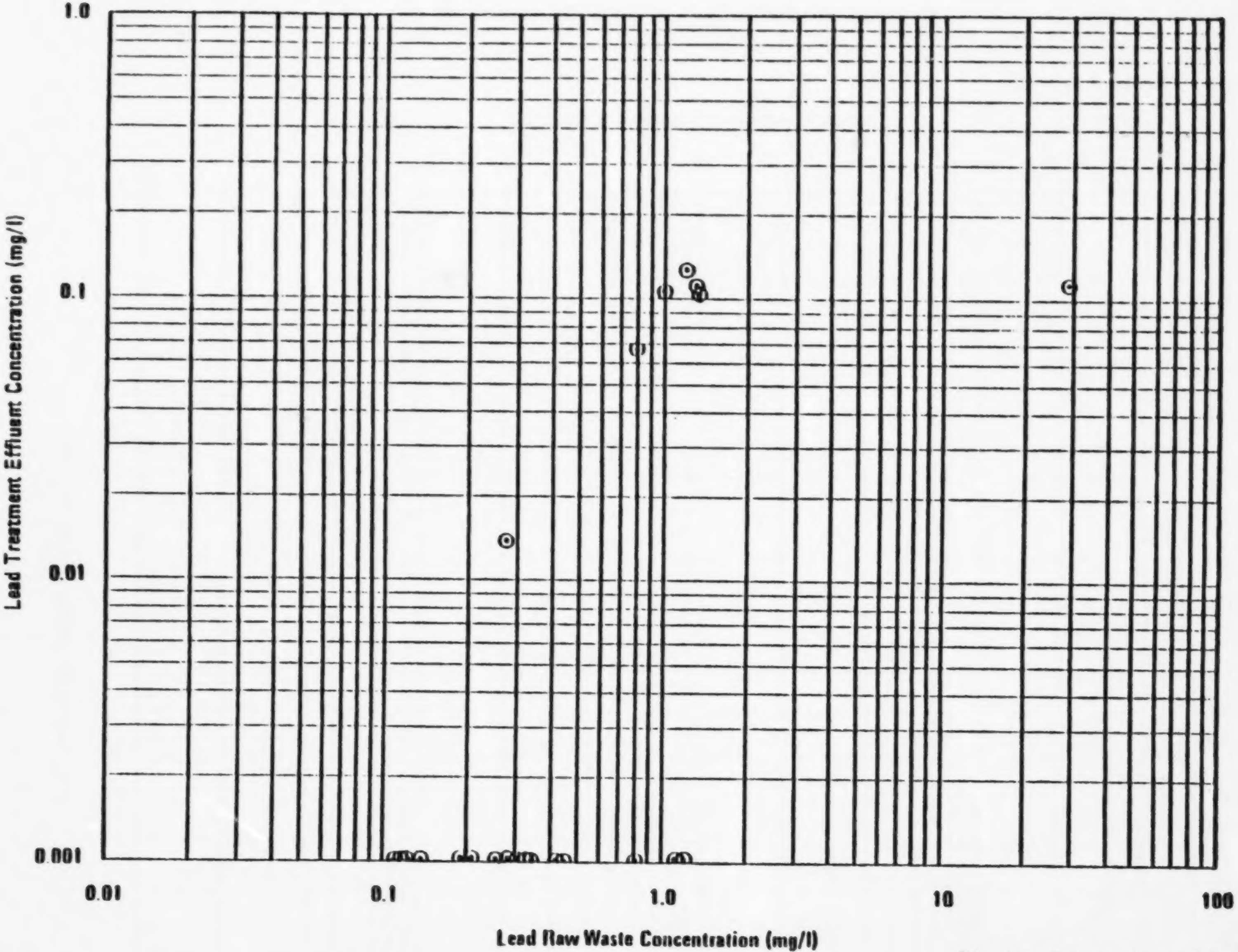
(Number of observations = 26)

FIGURE VII – 12
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
CHROMIUM



(Number of observations = 19)

FIGURE VII -13
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
COPPER



(Number of observations = 23)

FIGURE VII – 14
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
LEAD

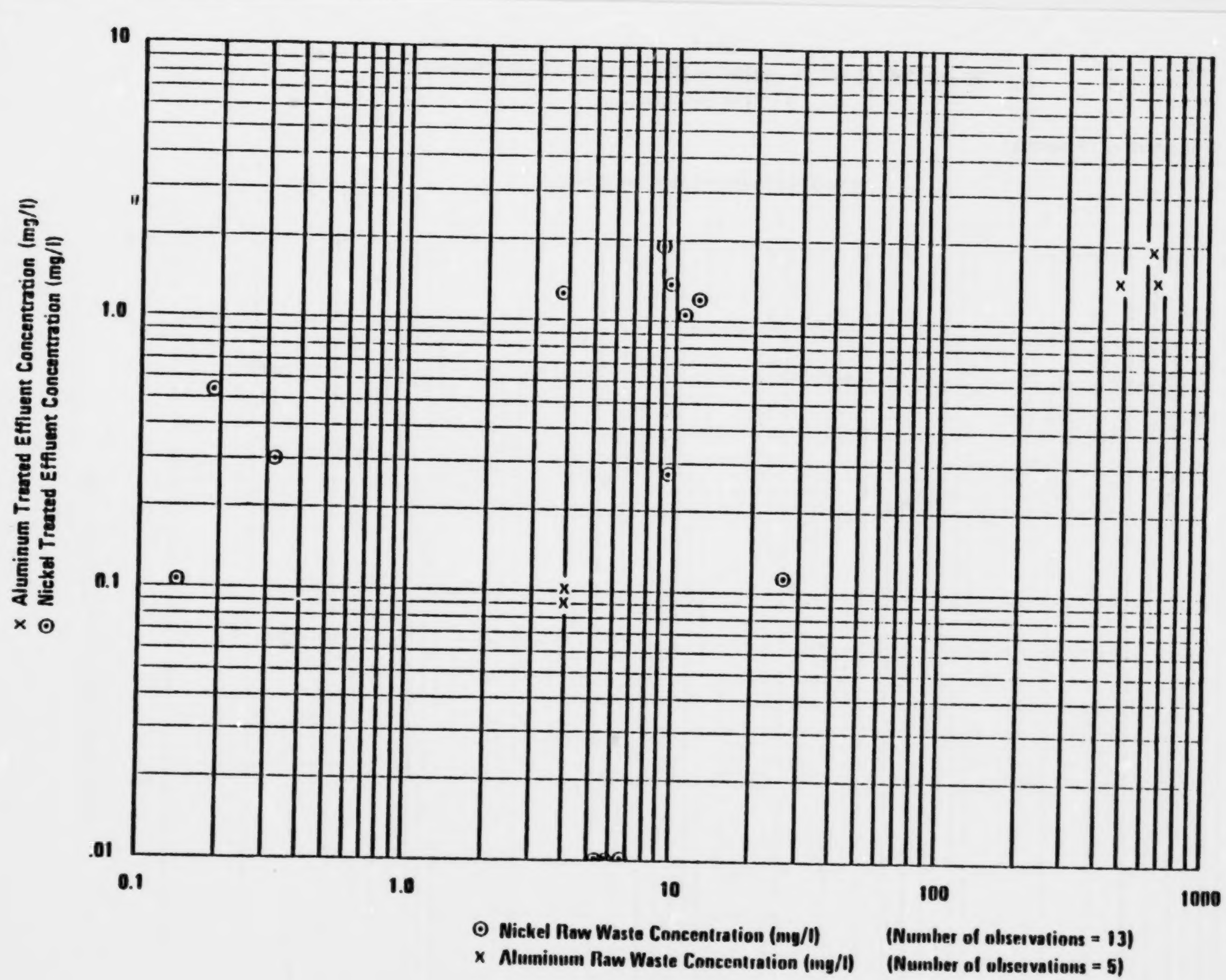
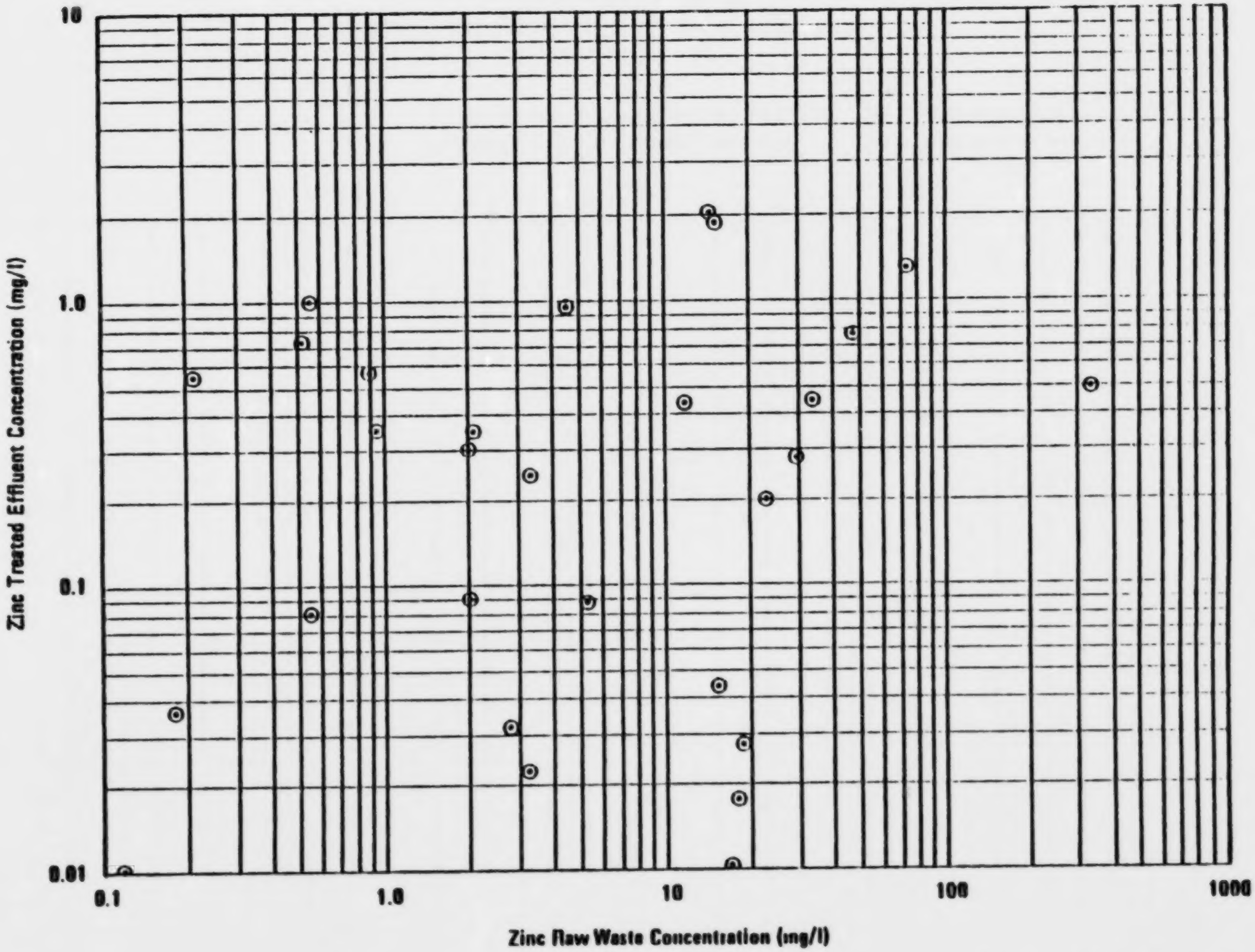
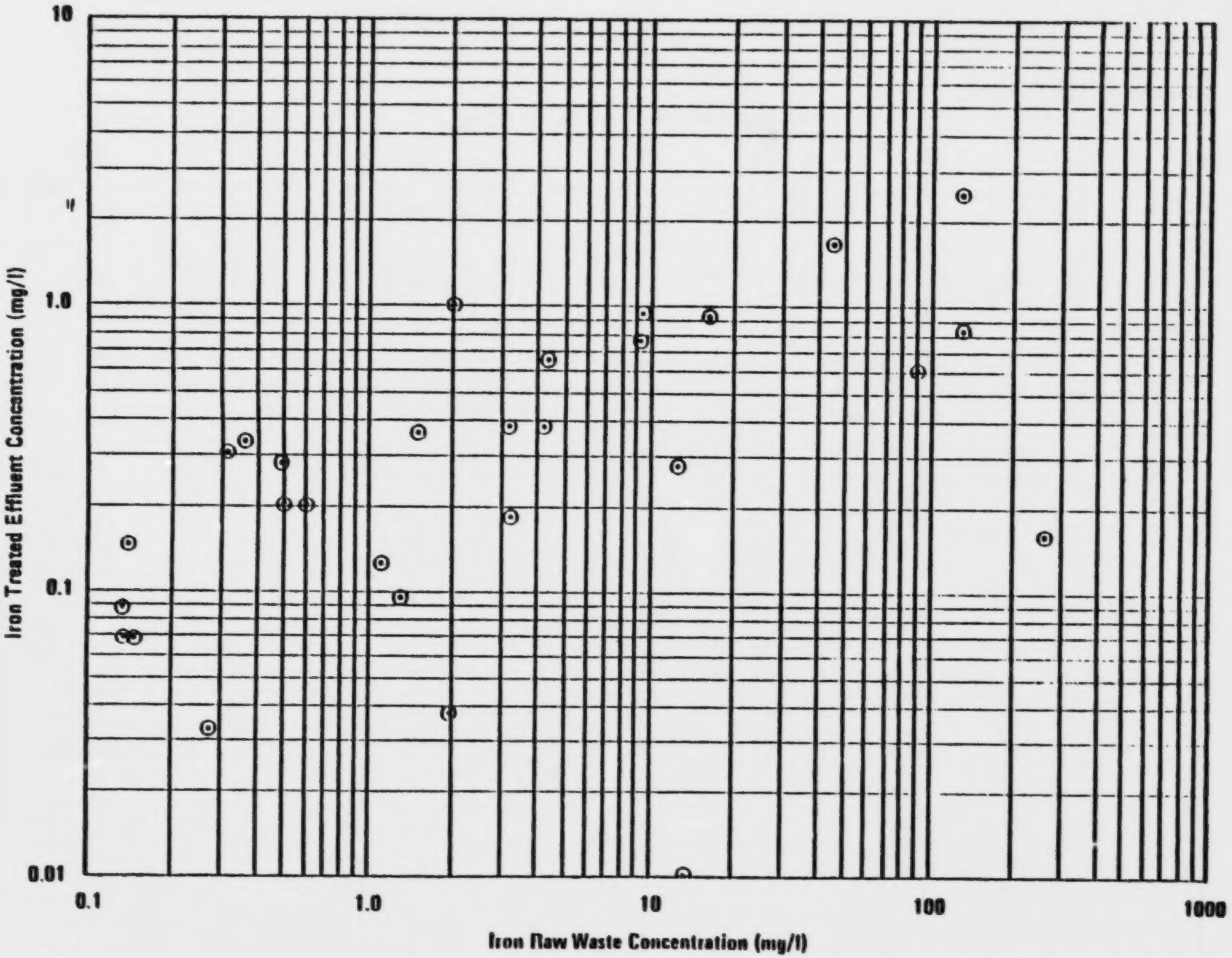


FIGURE VII-15
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
NICKEL AND ALUMINUM



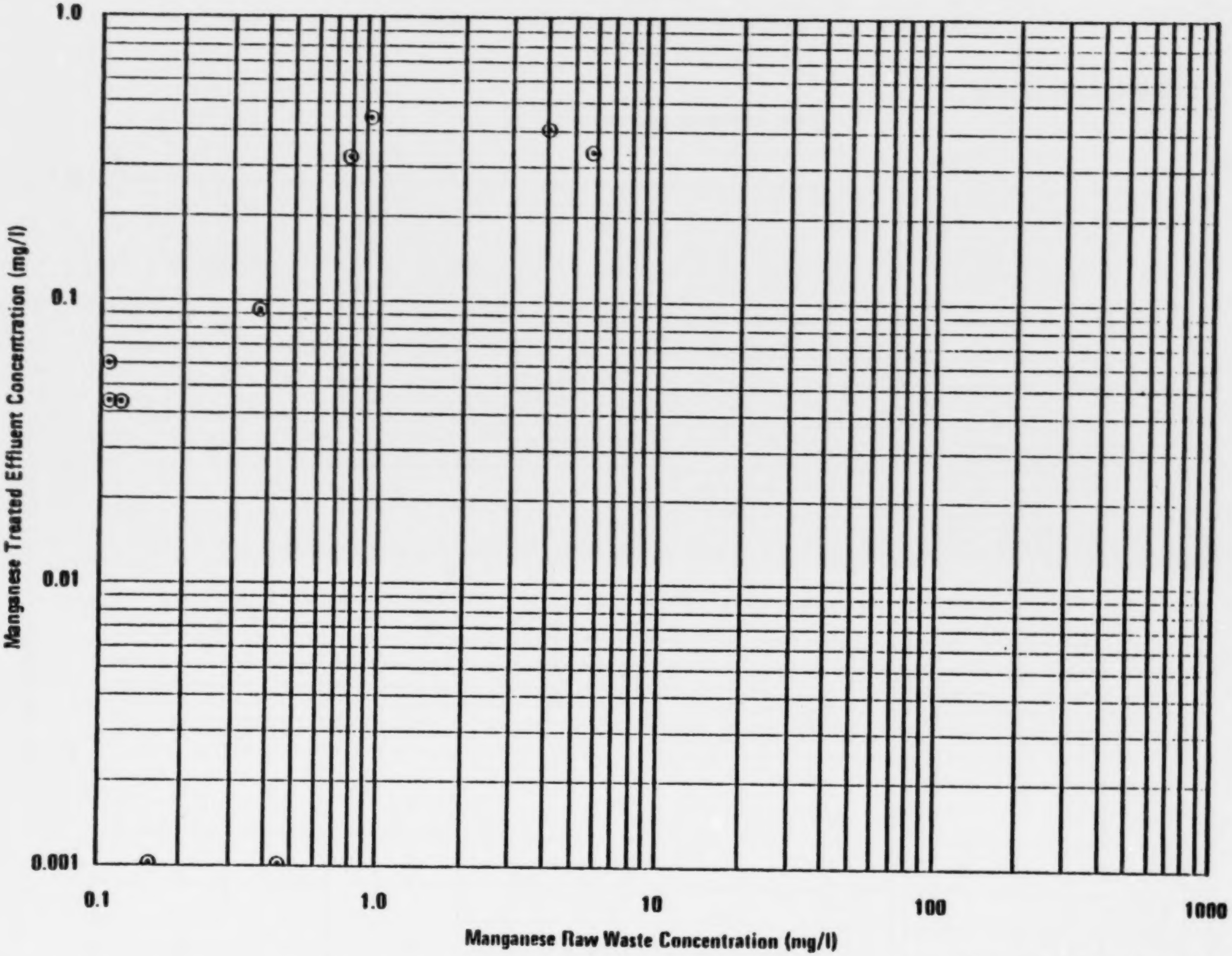
(Number of observations = 29)

FIGURE VII-16
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
ZINC



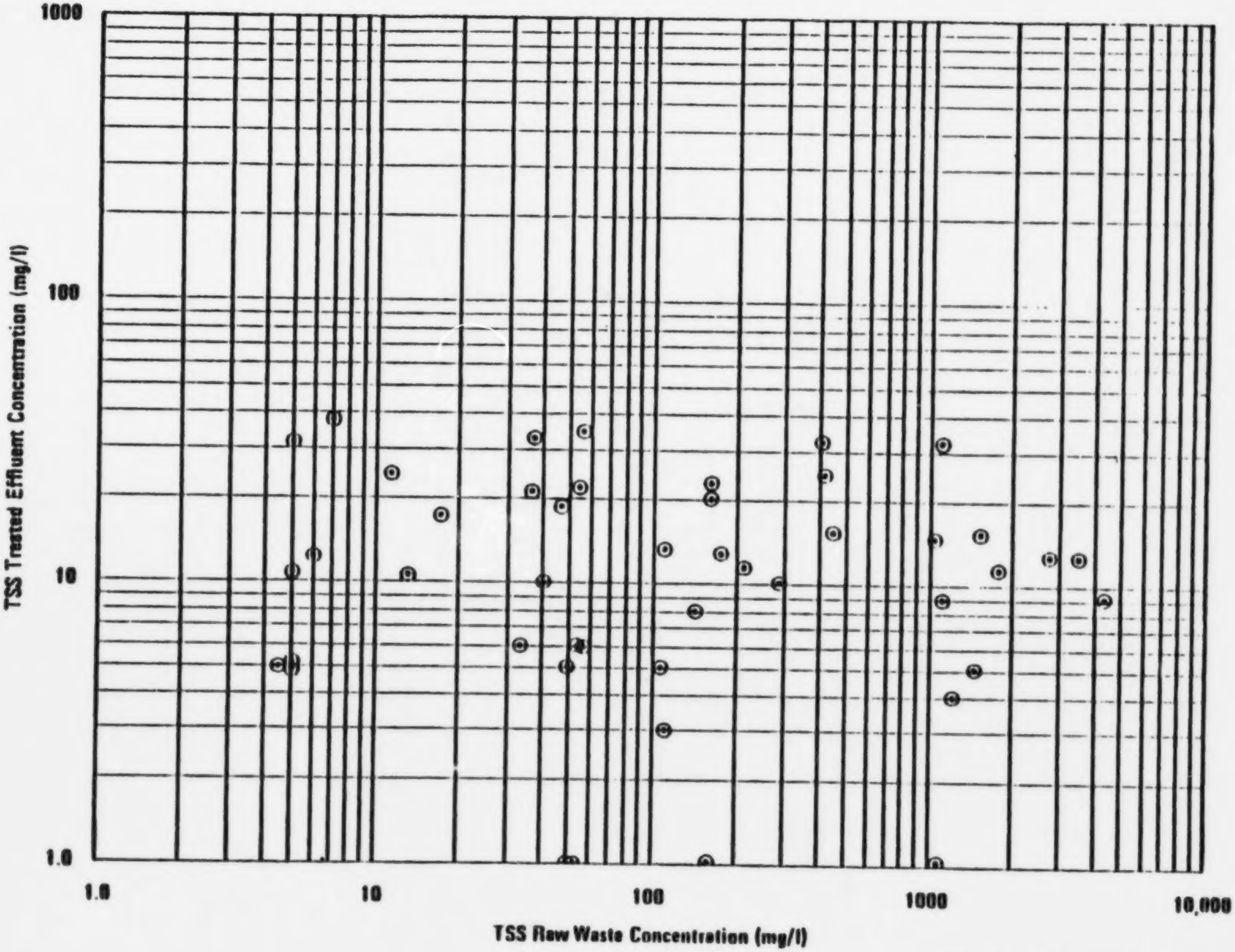
(Number of observations = 29)

FIGURE VII – 17
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
IRON



(Number of observations = 10)

FIGURE VII –18
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
MANGANESE



(Number of observations - 46)

FIGURE VII -19
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
TSS

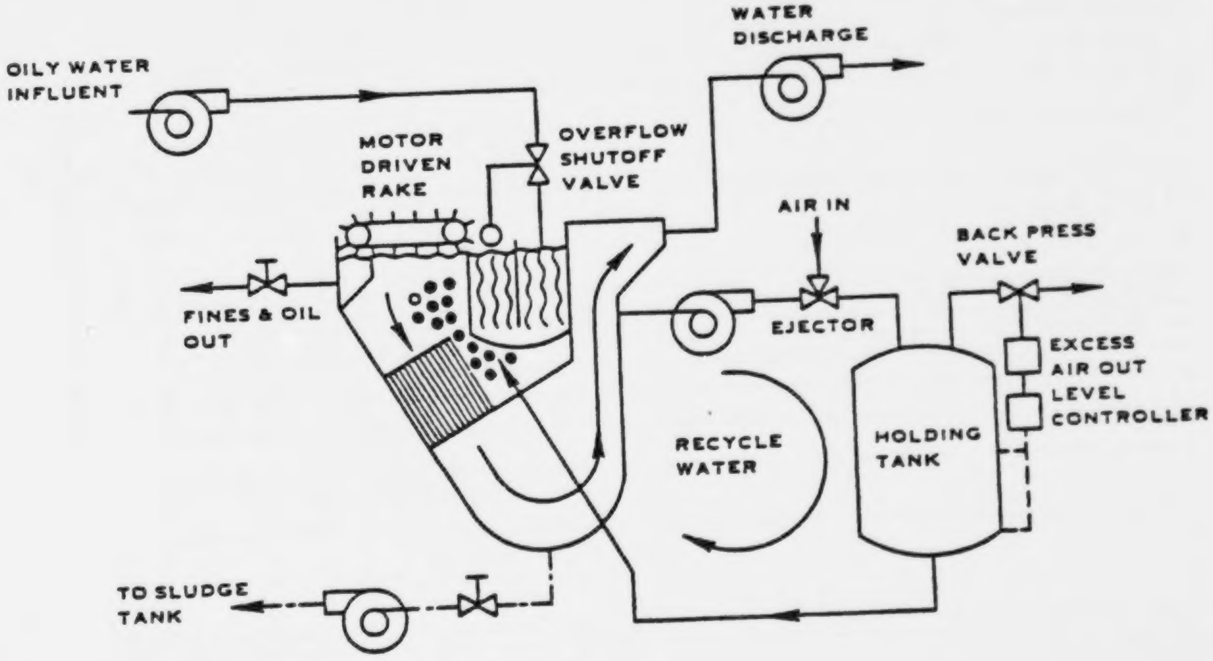

WATER DISCHARGE
OILY WATER INFLUENT
MOTOR DRIVEN RAKE
OVERFLOW SHUTOFF VALVE
AIR IN
BACK PRESS VALVE
FINES & OIL OUT
EJECTOR
EXCESS AIR OUT
LEVEL CONTROLLER
RECYCLE WATER
HOLDING TANK
TO SLUDGE TANK

Figure VII-20

DISSOLVED AIR FLOTATION

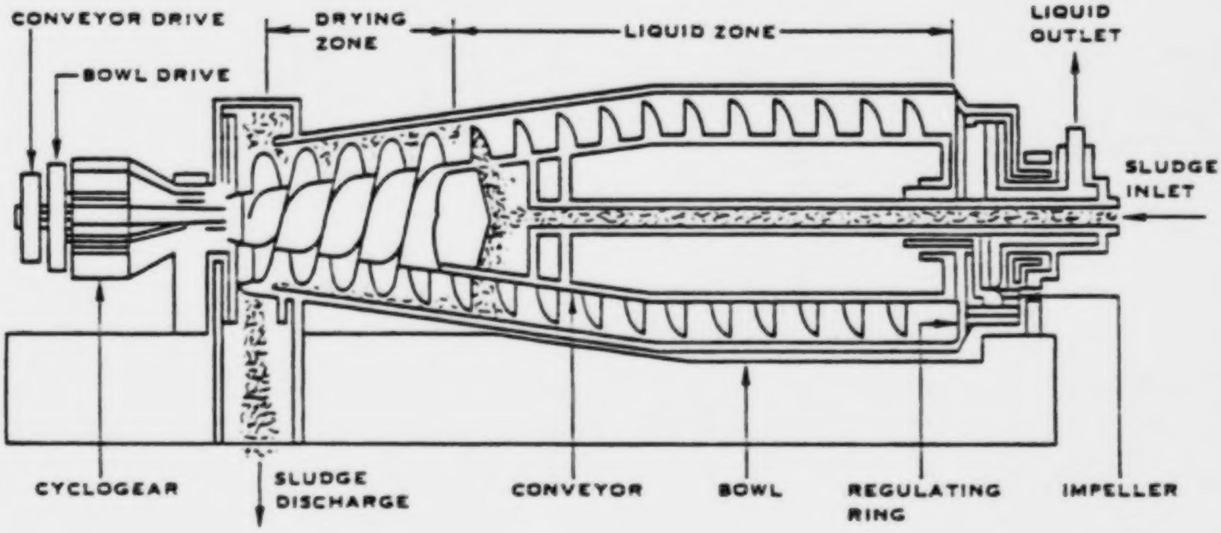

CONVEYOR DRIVE
BOWL DRIVE
DRYING ZONE
LIQUID ZONE
LIQUID OUTLET
SLUDGE INLET
CYCLOGEAR
SLUDGE DISCHARGE
CONVEYOR
BOWL
REGULATING RING
IMPELLER

Figure VII-21

CENTRIFUGATION

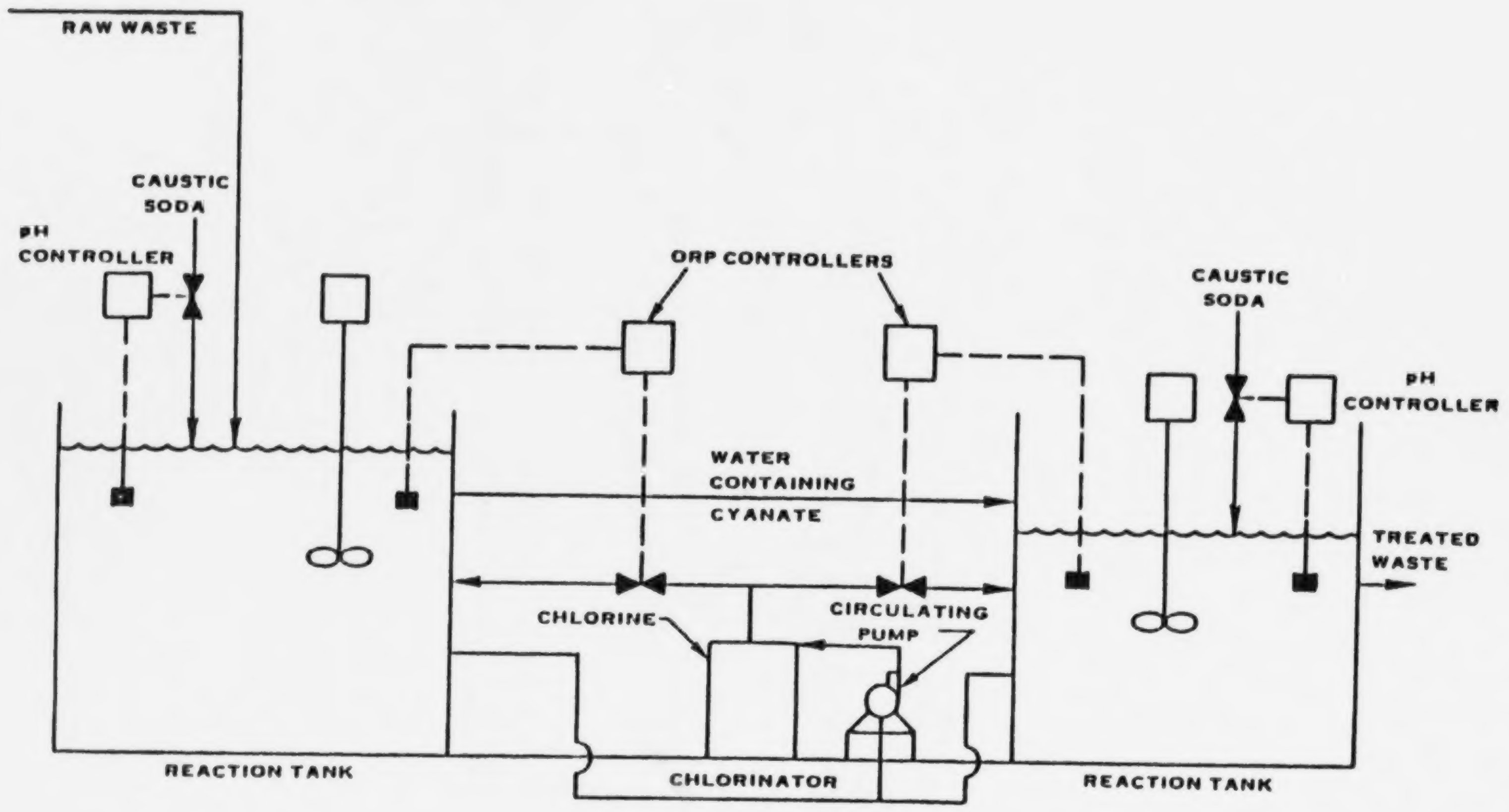

RAW WASTE
CAUSTIC SODA
pH CONTROLLER
ORP CONTROLLERS
CAUSTIC SODA
pH CONTROLLER
WATER CONTAINING CYANATE
TREATED WASTE
CHLORINE
CIRCULATING PUMP
REACTION TANK
CHLORINATOR
REACTION TANK

Figure VII-22

TREATMENT OF CYANIDE WASTE BY ALKALINE CHLORINATION

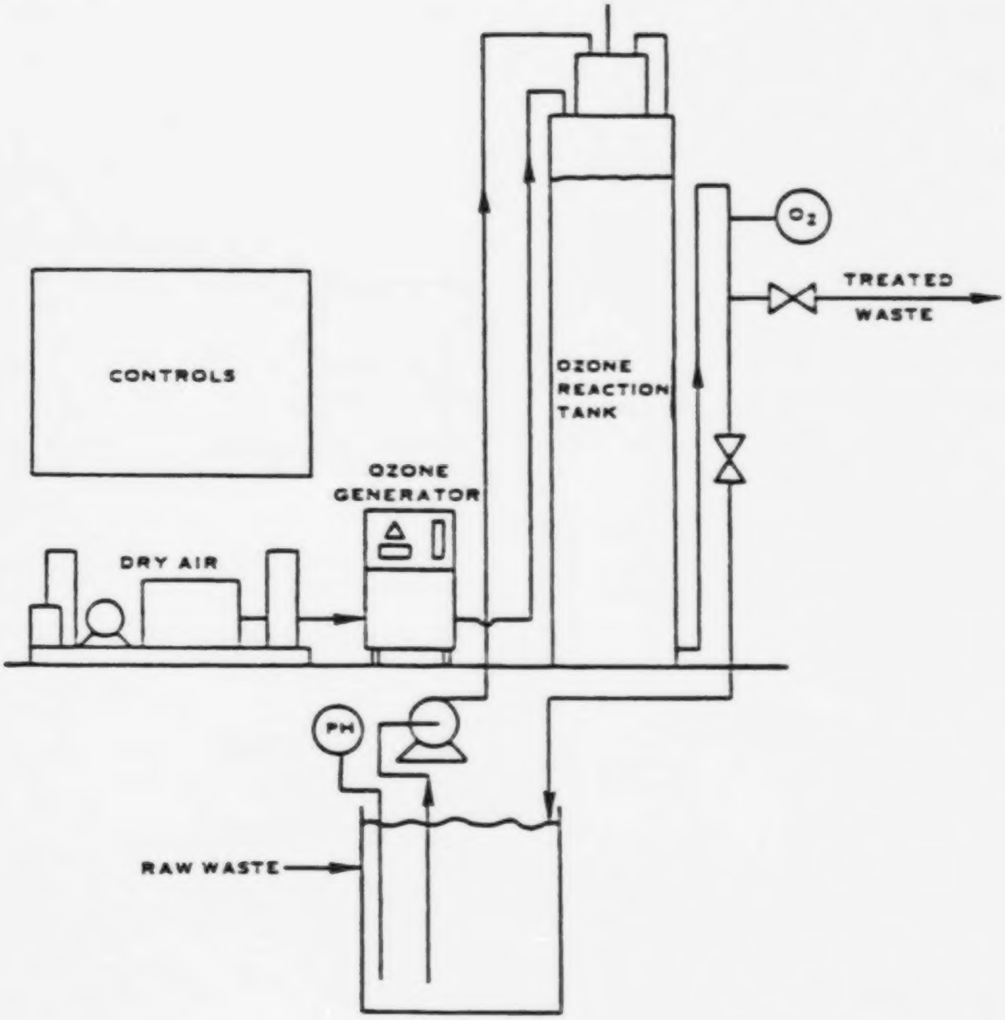

CONTROLS
OZONE GENERATOR
DRY AIR
OZONE REACTION TANK
O2
TREATED WASTE
PH
RAW WASTE

Figure VII-23

TYPICAL OZONE PLANT FOR WASTE TREATMENT

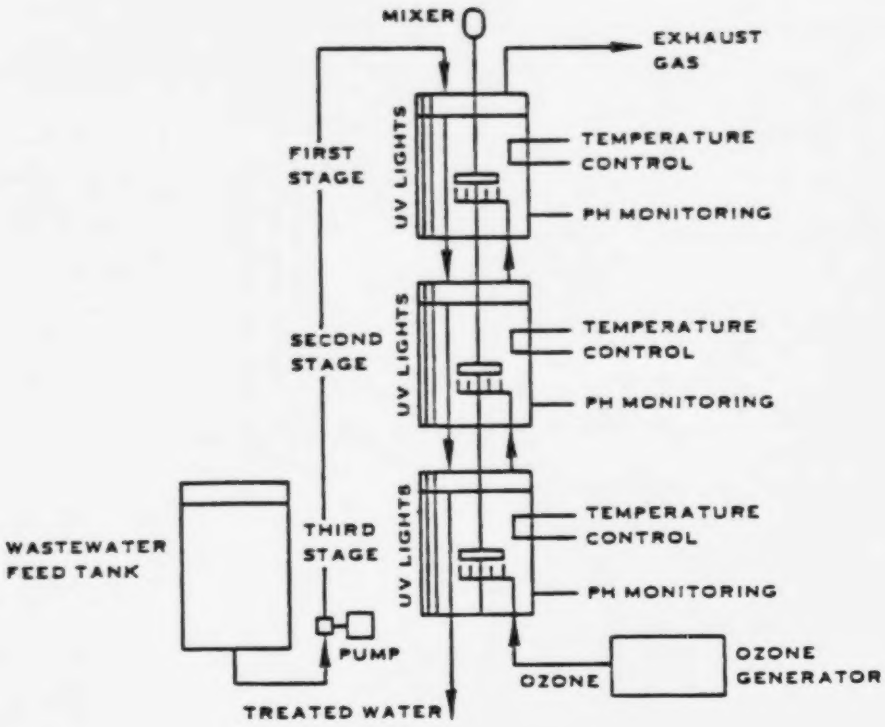
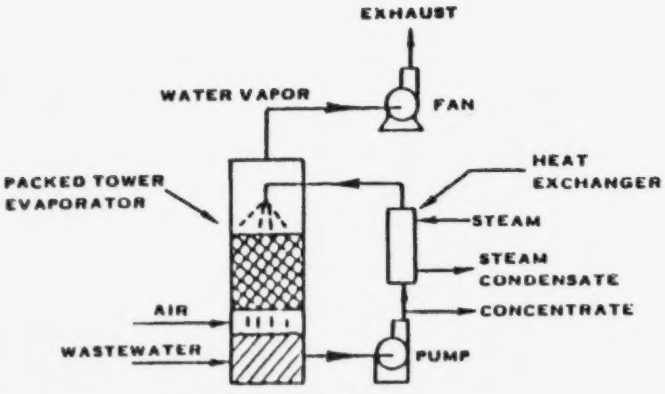
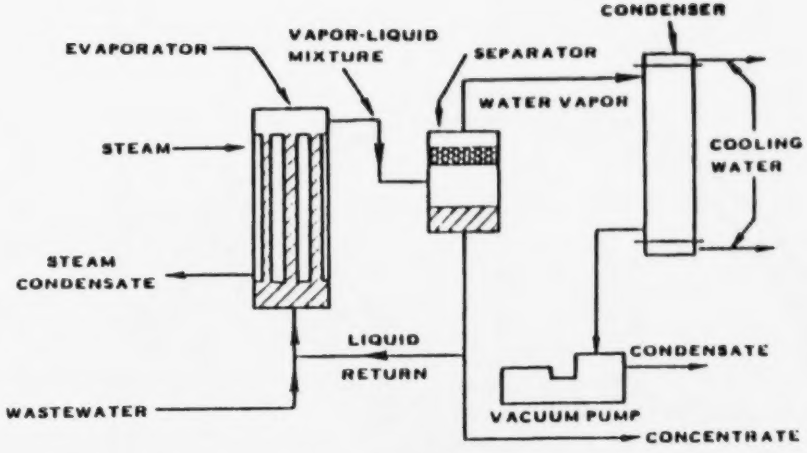

MIXER
EXHAUST GAS
FIRST STAGE
UV LIGHTS
TEMPERATURE CONTROL
PH MONITORING
SECOND STAGE
UV LIGHTS
TEMPERATURE CONTROL
PH MONITORING
WASTEWATER FEED TANK
THIRD STAGE
UV LIGHTS
TEMPERATURE CONTROL
PH MONITORING
PUMP
TREATED WATER
OZONE
OZONE GENERATOR

Figure VII-24

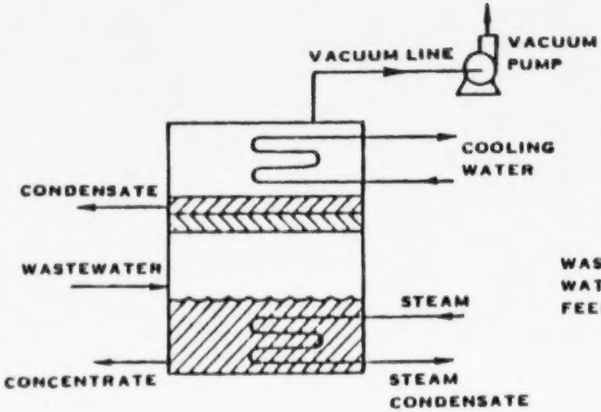
UV/OZONATION


EXHAUST
WATER VAPOR
FAN
PACKED TOWER EVAPORATOR
HEAT EXCHANGER
STEAM
STEAM CONDENSATE
AIR
CONCENTRATE
WASTEWATER
PUMP

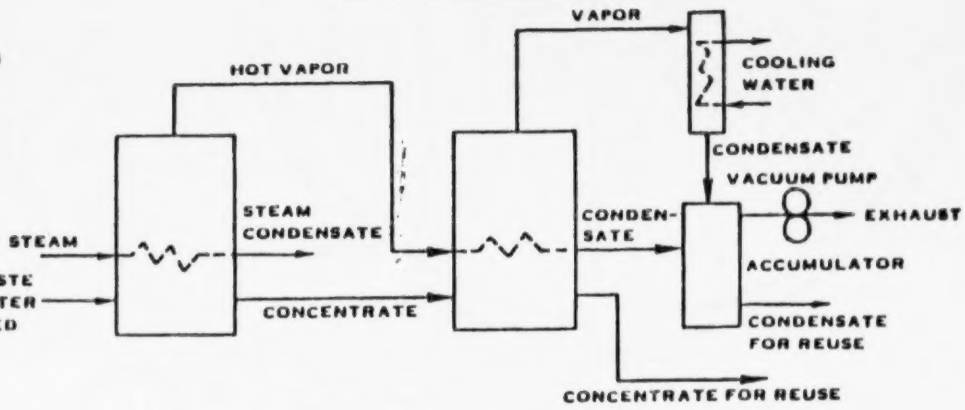
ATMOSPHERIC EVAPORATOR


EVAPORATOR
VAPOR-LIQUID MIXTURE
SEPARATOR
CONDENSER
WATER VAPOR
STEAM
COOLING WATER
STEAM CONDENSATE
LIQUID RETURN
CONDENSATE
WASTEWATER
VACUUM PUMP
CONCENTRATE

CLIMBING FILM EVAPORATOR


VACUUM LINE
VACUUM PUMP
COOLING WATER
CONDENSATE
WASTEWATER
STEAM
CONCENTRATE
STEAM CONDENSATE

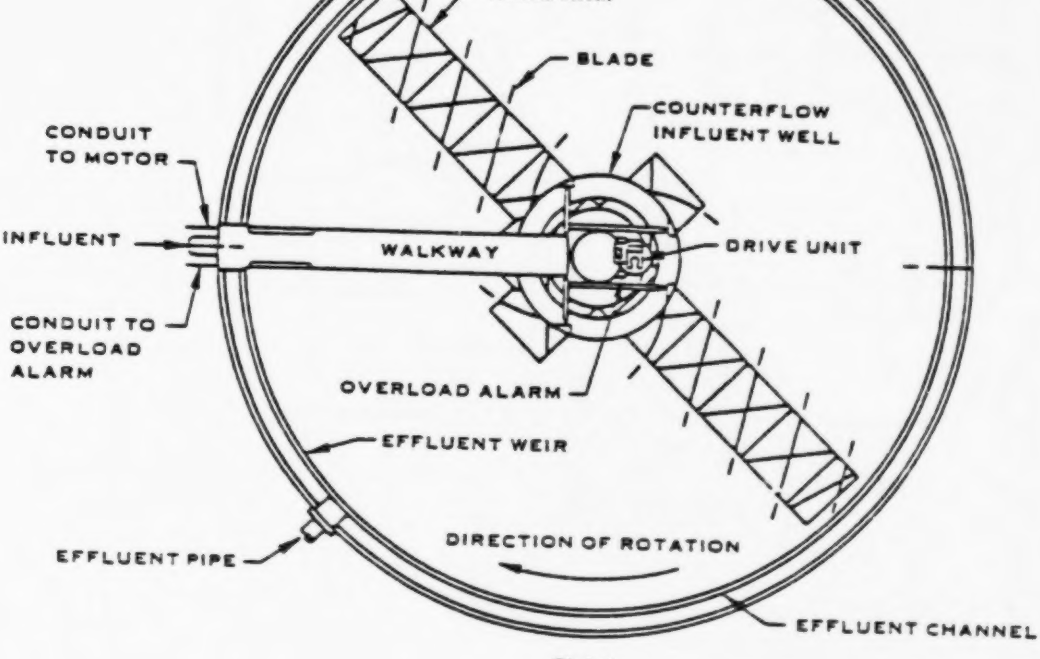
SUBMERGED TUBE EVAPORATOR


VAPOR
HOT VAPOR
COOLING WATER
CONDENSATE
VACUUM PUMP
STEAM
STEAM CONDENSATE
CONDEN-SATE
EXHAUST
ACCUMULATOR
WASTE WATER FEED
CONCENTRATE
CONDENSATE FOR REUSE
CONCENTRATE FOR REUSE

DOUBLE-EFFECT EVAPORATOR

Figure VII-25

TYPES OF EVAPORATION EQUIPMENT


RAKE ARM
BLADE
COUNTERFLOW INFLUENT WELL
CONDUIT TO MOTOR
INFLUENT
WALKWAY
DRIVE UNIT
CONDUIT TO OVERLOAD ALARM
OVERLOAD ALARM
EFFLUENT WEIR
EFFLUENT PIPE
DIRECTION OF ROTATION
EFFLUENT CHANNEL

PLAN

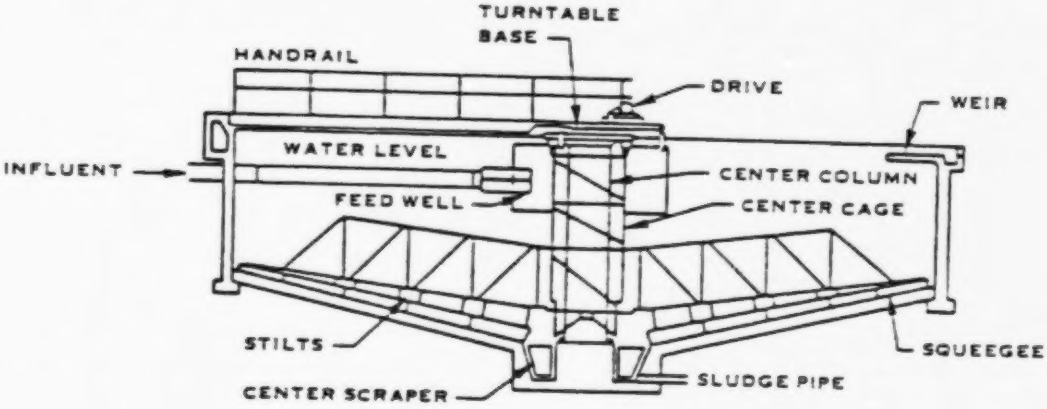

TURNTABLE BASE
HANDRAIL
DRIVE
WEIR
WATER LEVEL
INFLUENT
CENTER COLUMN
FEED WELL
CENTER CAGE
STILTS
SQUEEGEE
CENTER SCRAPER
SLUDGE PIPE

Figure VII-26

GRAVITY THICKENING

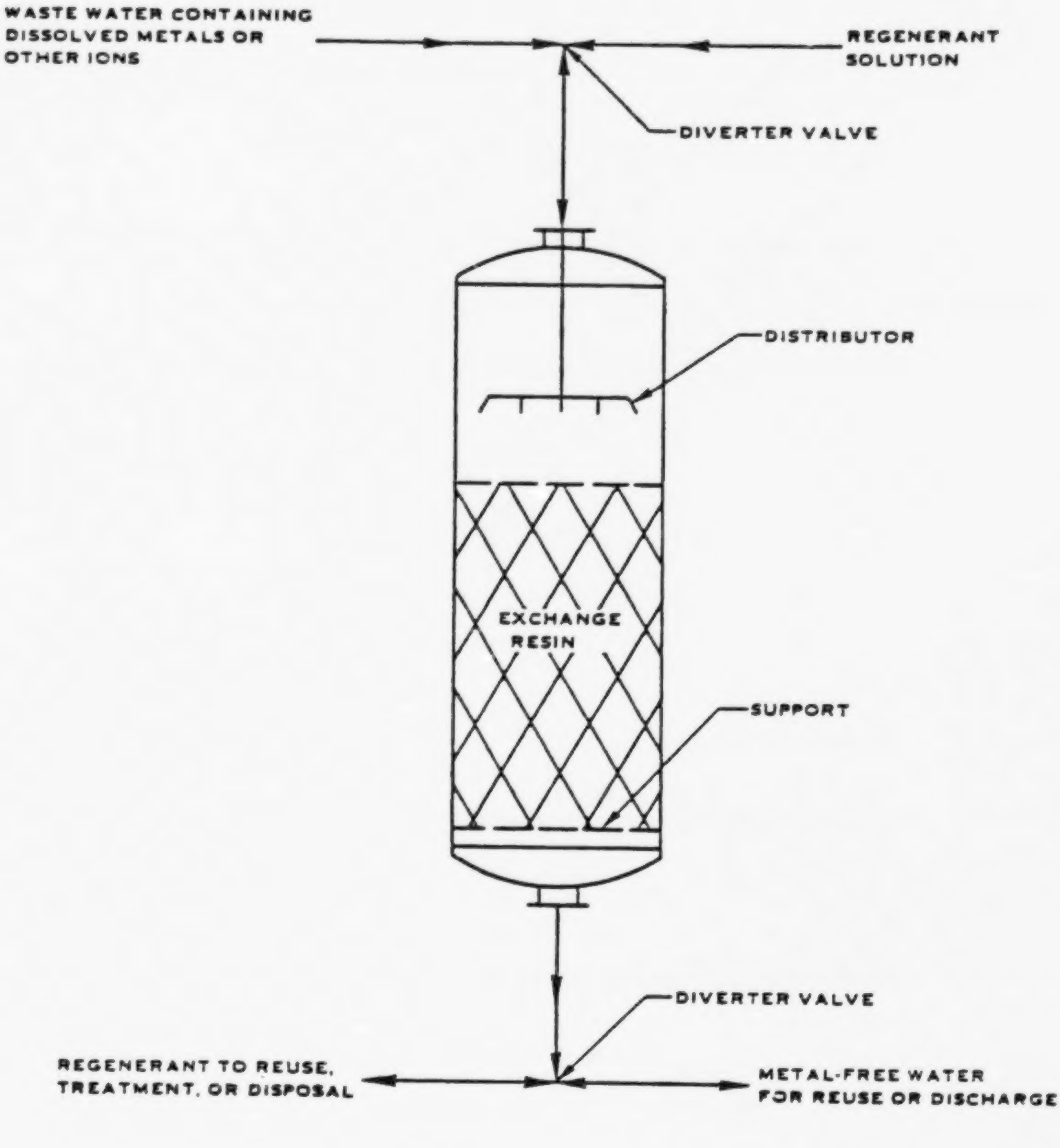

WASTE WATER CONTAINING DISSOLVED METALS OR OTHER IONS
REGENERANT SOLUTION
DIVERTER VALVE
DISTRIBUTOR
EXCHANGE RESIN
SUPPORT
DIVERTER VALVE
REGENERANT TO REUSE, TREATMENT, OR DISPOSAL
METAL-FREE WATER FOR REUSE OR DISCHARGE

Figure VII-27

ION EXCHANGE WITH REGENERATION

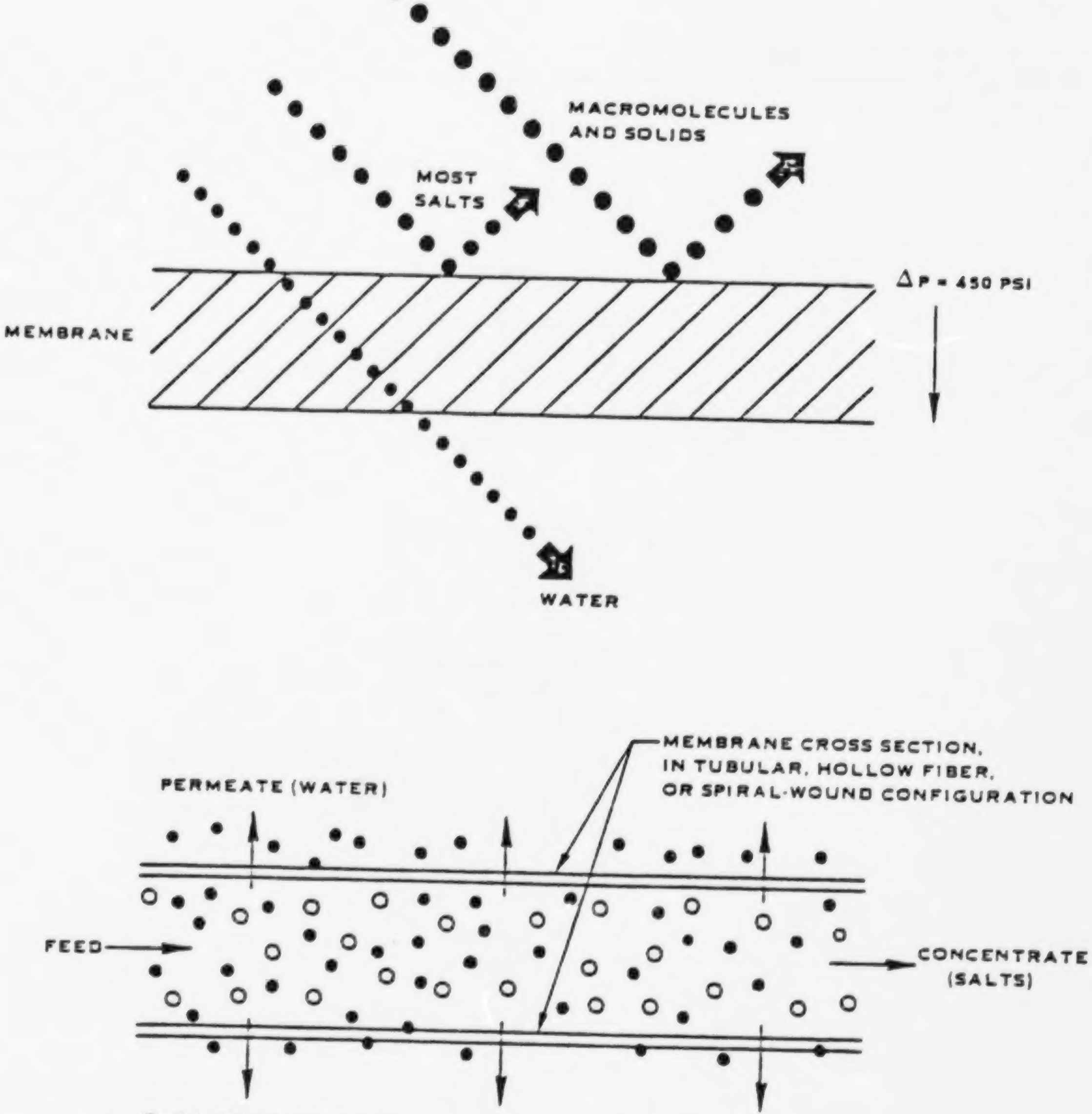
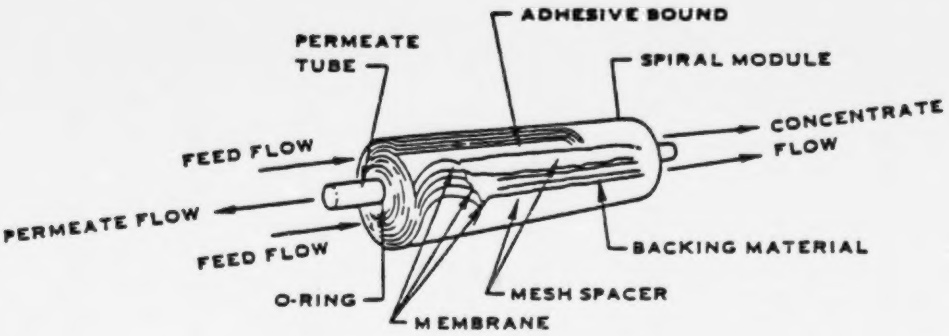
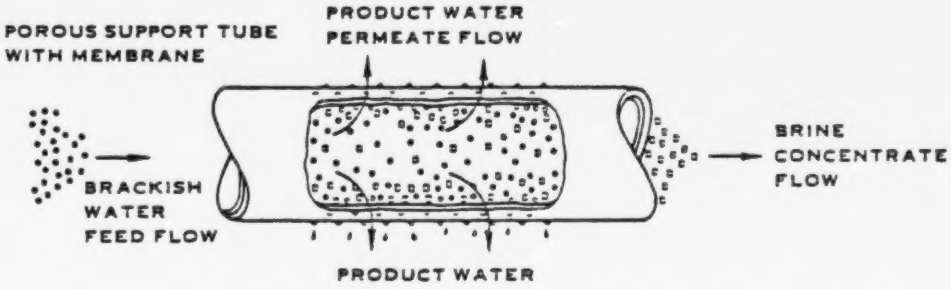

MACROMOLECULES
AND SOLIDS
MOST
SALTS
ΔP = 450 PSI
MEMBRANE
WATER
MEMBRANE CROSS SECTION,
IN TUBULAR, HOLLOW FIBER,
OR SPIRAL-WOUND CONFIGURATION
PERMEATE (WATER)
FEED
CONCENTRATE
(SALTS)
○ SALTS OR SOLIDS
● WATER MOLECULES

Figure VII-28

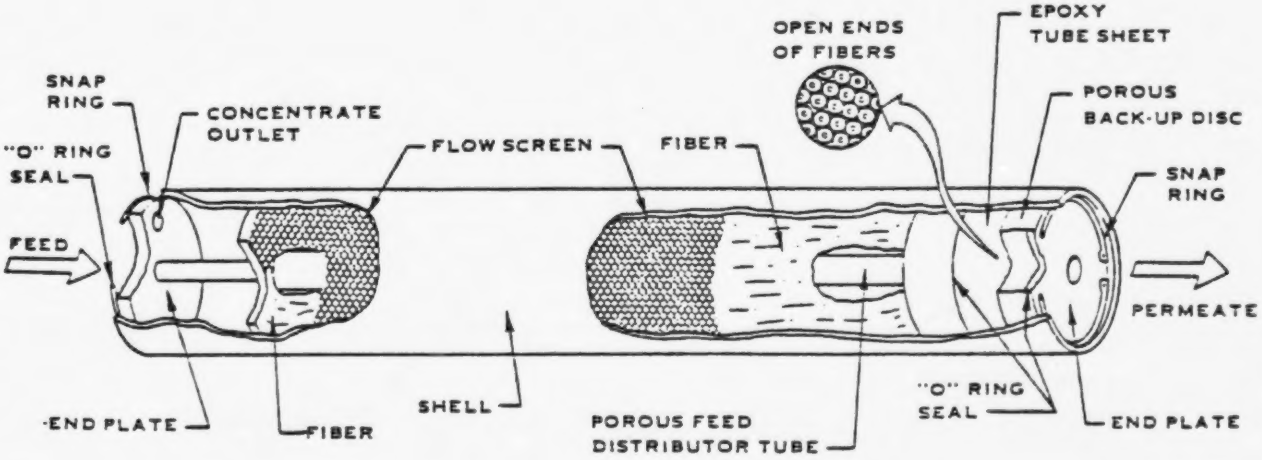
SIMPLIFIED REVERSE OSMOSIS SCHEMATIC


ADHESIVE BOUND
PERMEATE TUBE
SPIRAL MODULE
CONCENTRATE FLOW
FEED FLOW
PERMEATE FLOW
FEED FLOW
BACKING MATERIAL
O-RING
MESH SPACER
MEMBRANE

SPIRAL MEMBRANE MODULE


POROUS SUPPORT TUBE WITH MEMBRANE
PRODUCT WATER PERMEATE FLOW
BRINE CONCENTRATE FLOW
BRACKISH WATER FEED FLOW
PRODUCT WATER

TUBULAR REVERSE OSMOSIS MODULE


OPEN ENDS OF FIBERS
EPOXY TUBE SHEET
SNAP RING
CONCENTRATE OUTLET
POROUS BACK-UP DISC
"O" RING SEAL
FLOW SCREEN
FIBER
SNAP RING
FEED
PERMEATE
SHELL
"O" RING SEAL
END PLATE
FIBER
POROUS FEED DISTRIBUTOR TUBE
END PLATE

HOLLOW FIBER MODULE

Figure VII-29

REVERSE OSMOSIS MEMBRANE CONFIGURATIONS

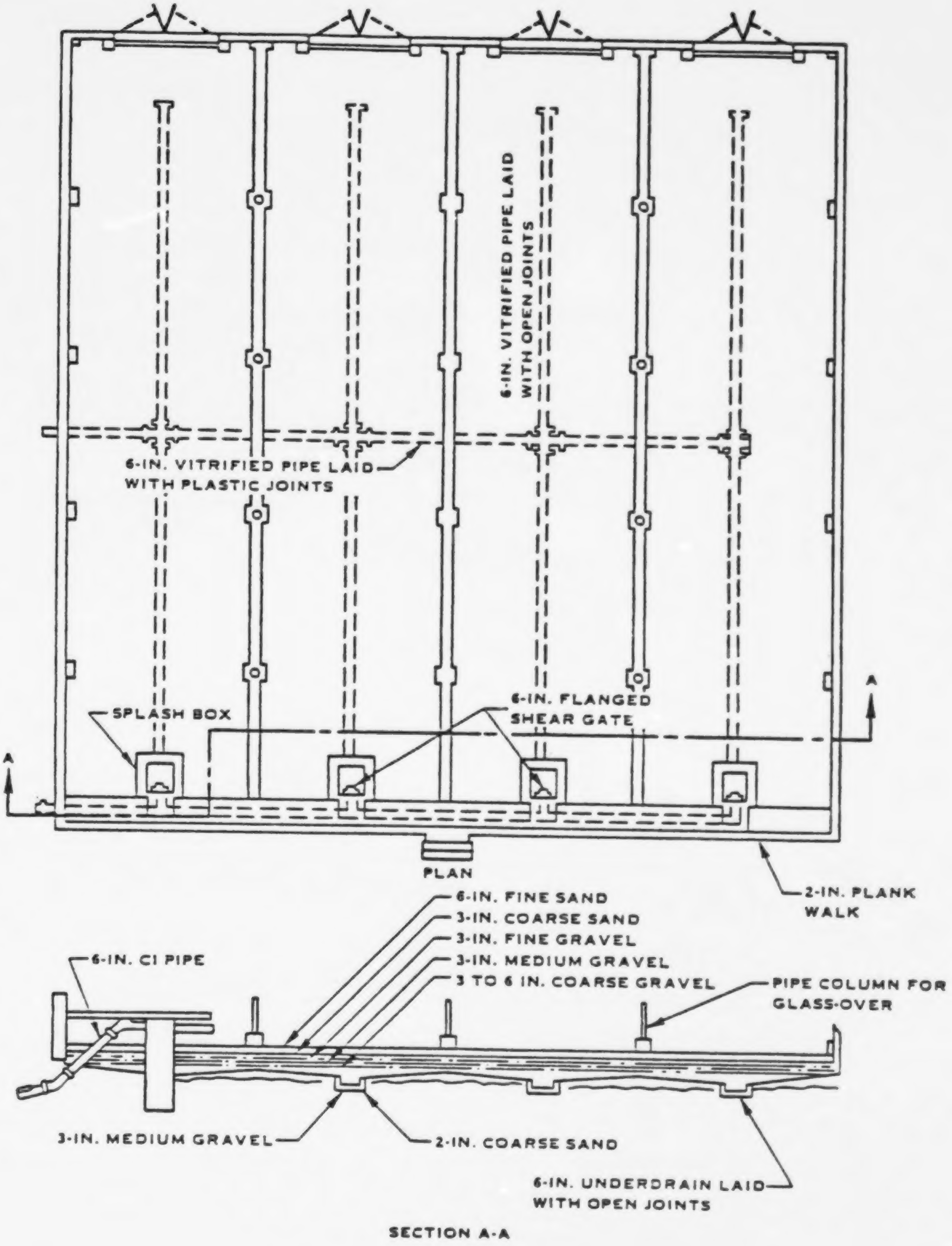

6-IN. VITRIFIED PIPE LAID
WITH OPEN JOINTS
6-IN. VITRIFIED PIPE LAID
WITH PLASTIC JOINTS
SPLASH BOX
6-IN. FLANGED
SHEAR GATE
A
A
PLAN
2-IN. PLANK
WALK
6-IN. FINE SAND
3-IN. COARSE SAND
3-IN. FINE GRAVEL
3-IN. MEDIUM GRAVEL
3 TO 6 IN. COARSE GRAVEL
6-IN. CI PIPE
PIPE COLUMN FOR
GLASS-OVER
3-IN. MEDIUM GRAVEL
2-IN. COARSE SAND
6-IN. UNDERDRAIN LAID
WITH OPEN JOINTS
SECTION A-A

Figure VII-30
SLUDGE DRYING BED

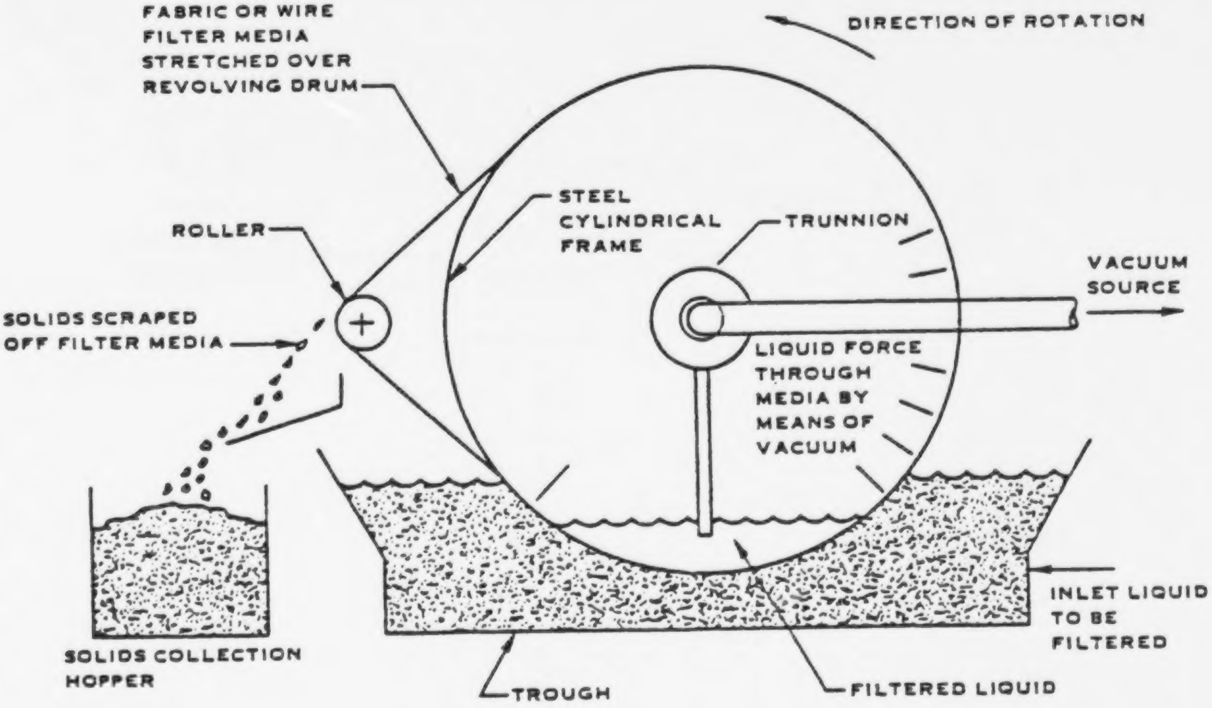

FABRIC OR WIRE FILTER MEDIA STRETCHED OVER REVOLVING DRUM
DIRECTION OF ROTATION
STEEL CYLINDRICAL FRAME
TRUNNION
ROLLER
VACUUM SOURCE
SOLIDS SCRAPED OFF FILTER MEDIA
LIQUID FORCE THROUGH MEDIA BY MEANS OF VACUUM
INLET LIQUID TO BE FILTERED
SOLIDS COLLECTION HOPPER
TROUGH
FILTERED LIQUID

Figure VII-31

VACUUM FILTRATION

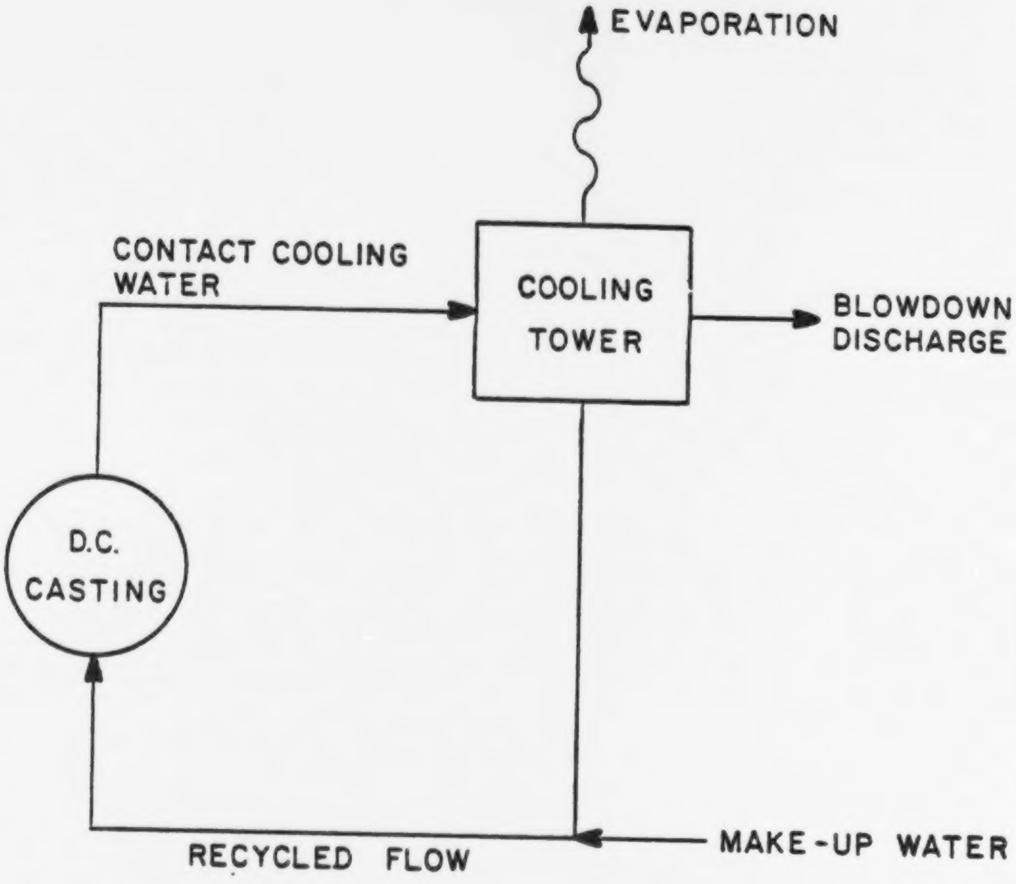

EVAPORATION
CONTACT COOLING WATER
COOLING TOWER
BLOWDOWN DISCHARGE
D.C. CASTING
RECYCLED FLOW
MAKE-UP WATER

Figure VII-32

FLOW DIAGRAM FOR RECYCLING WITH A COOLING TOWER

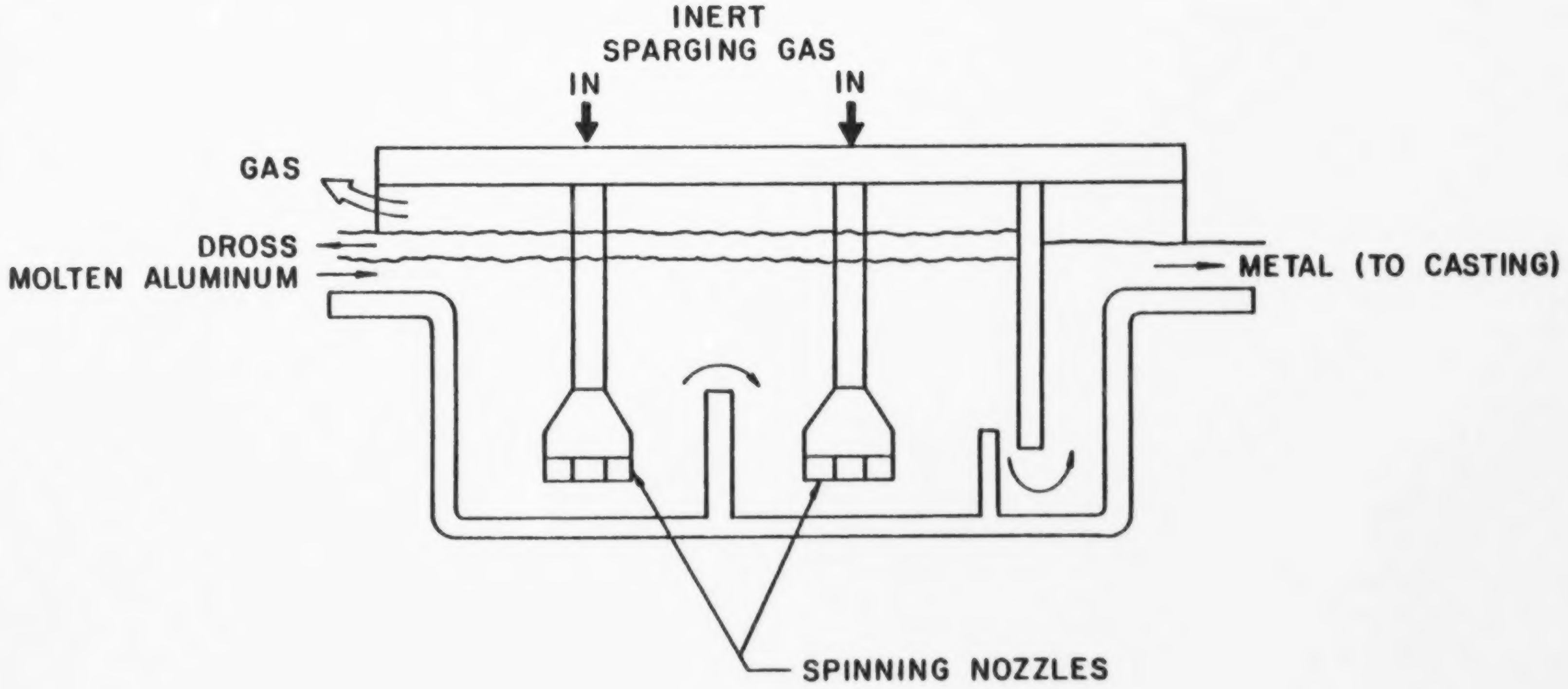

INERT
SPARGING GAS
IN
IN
GAS
DROSS
MOLTEN ALUMINUM
METAL (TO CASTING)
SPINNING NOZZLES

Figure VII-33

SCHEMATIC DIAGRAM OF SPINNING NOZZLE ALUMINUM REFINING PROCESS

SECTION VIII

COST, ENERGY, AND NONWATER QUALITY ASPECTS

Cost information for the treatment options considered in establishing these effluent limitations and standards is presented in the following discussion. This section presents general information pertaining to the development of capital and annual costs. Several levels of effluent reduction are presented for each waste stream in every subcategory. The cost curves drafted for use in estimating plant costs are presented in each of the subcategory supplements. After discussing the basis of the cost estimates, this section presents the specific procedures for developing costs for each technology for existing sources. The section concludes with a discussion of the energy and nonwater quality aspects of the treatment options.

BASIS FOR COST ESTIMATION

Sources of Cost Data

Capital and annual cost data for the selected treatment processes were collected from four sources: (1) literature, (2) data collection portfolios, (3) equipment manufacturers, and (4) in-house design projects. The majority of the cost information was obtained from literature sources. Many of the literature sources cited obtained their costs from surveys of actual design projects. Data collection portfolios completed by companies in the nonferrous metals manufacturing category contained a limited amount of chemical and unit process cost information. Most of the dcp did not include treatment plant capital and annual cost information. Therefore, little data from the data collection portfolios was applicable for the determination of individual unit process costs. Additional data was obtained from equipment manufacturers and design projects performed by an EPA contractor.

Determination of Costs

The annualized costs developed for each level of treatment and combination of waste streams include amortization and depreciation of the investment cost, operation and maintenance costs, and monitoring costs. The summation curves included in each of the supplements present the cost of each alternative as a plot of annual cost ($/yr) versus plant flow (mgd). The dollar base is 4th quarter 1976.

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Investment (Capital) Cost Basis

Investment costs (capital expenditures) include:

1. Major and auxiliary equipment,
2. Piping and pumping,
3. Freight,
4. Sitework,
5. Installation,
6. Contractor's fees,
7. Electrical and instrumentation,
8. Yard piping,
9. Engineering, and
10. Contingency.

For technologies currently in use, i.e., chemical precipitation, sedimentation, cyanide precipitation, vacuum filtration, multi-media filtration, pH adjustment, activated alumina adsorption, activated carbon adsorption, steam stripping, reverse osmosis, and flow reduction using holding tank and cooling towers, cost data were gathered from current bids, from the literature and from other sources as described above.

The cost information was equalized by updating or backdating all the costs to the 4th quarter of 1976. The national average EPA-Sewage Treatment Plant (STP) index and the EPA-Large City Advanced Treatment (LCAT) index were both considered for use in updating the costs for preliminary engineering estimates. The EPA-LCAT index was chosen most often because its component mix is indicative of the treatment processes presented herein, and was used by a majority of the references from which costs were obtained. The 4th quarter 1976 value of this index is 130, while the 1976 value of the EPA-STP index is 262. It should also be noted that the costs presented here are averages for the nation and, under specific regional market conditions, could vary as much as 40 percent. The factors in Figure VIII-1 can be used to modify the average capital costs for a particular location.

Total installed costs were broken into equipment and construction fractions shown in the table below. These figures represent the percentage of the installed cost of each item. For example, the installed cost of chemical precipitation is estimated to be 20 percent equipment and 80 percent construction.

Process	Equipment	Construction
Chemical Precipitation	20	80
Vacuum Filtration	35	65
Multi-Media Filtration	20	80
pH Adjustment	35	65
Activated Alumina Adsorption	50	50

Process	Equipment	Construction
Activated Carbon Adsorption	50	50
Steam Stripping	35	65
Reverse Osmosis	50	50
Holding Tank	50	50
Sedimentation	10	90
Cooling Tower	35	65

A contingency allowance of 15 percent of the installed cost was used to cover unexpected costs due to local plant conditions and differences between actual systems and those used for the cost estimates. No allowance was made for plant shutdown during construction. The need for a shutdown is dependent on the layout of each plant. Engineering costs were estimated by using a percentage of the installed cost plus contingencies. The percentage used was to the nearest 0.5 percent from curve A in Consulting Engineering (ASCE MOP #45), which is a plot of percent engineering costs versus construction costs.

Annual Cost Basis

Amortization. The annual cost of capital is a function of the investment cost, the interest rate, and the period of amortization. For the cost curves contained in this document and in the supplements, the capital costs were amortized at an interest rate of 7.75 percent over a 20-year period. This results in an annual cost of capital of 10 percent of the investment. The amortization and depreciation costs in this document are presented for the sake of completeness. The economic impact analysis document should be consulted for the methods of amortization and depreciation that were actually used to assess the economic impact for this category. A summary of these methods is presented in the specific plant costing section below.

Depreciation. The estimated useful lives of the components of each alternative were established to calculate depreciation, a non-cash annual expense that accounts for obsolescence and retirement of the asset. The useful lives for each component are estimated as follows:

Technology	Useful Life (Years)
Chemical Precipitation	25
Vacuum Filtration	15
Filtration	15
pH Adjustment	15
Activated Alumina Adsorption	15

Technology	Useful Life (Years)
Activated Carbon Adsorption	15
Steam Stripping	15
Reverse Osmosis	20
Holding Tank	20
Sedimentation	25
Cooling Tower	15

To calculate the useful life of a treatment option, the sum of the products of the cost and the useful life for each component is divided by the sum of the costs. This weights the useful life by the cost of each component in the alternative. The installed cost plus contingencies were depreciated on a straight line basis for the calculated life of each alternative.

Operation and Maintenance Labor. Estimates of the annual man-hours required to operate and maintain the various systems were developed from the literature. A productive work value of 6.5 hr/man/day, or 1,500 hr/yr/man was assumed. A rate of $15/hr was used as the total cost for wages, benefits, and overhead expenses. Supervisory, administrative, clerical, and laboratory man-hours were developed and are included in the O&M labor costs. Figure VIII-2 shows how the wage rates will vary with location throughout the U.S. The factors shown can be multiplied by the assumed rate of $15/hr to obtain the wage rate at that location.

Maintenance Materials. The annual costs of materials and parts needed to maintain each process were developed from the literature and equipment manufacturers.

Chemicals. The assumptions used to estimate chemical requirements are listed below for each module that requires chemicals.

The costs of chemicals were assumed to be as follows:

Chemical	Cost ($/ton) - 4th quarter 1976
Lime (CaO)	30
SO_2	130
Activated Alumina	340
Activated Carbon	1,000
NaOH (50% liquid)	160
H_2SO_4 (66° Be')	47

Energy and Power. Operating time for all equipment of all the treatment alternatives, with the exception of vacuum filtration, was assumed to be 24 hrs/day and 300 days/yr. Vacuum filters were sized to operate 10 hrs/day, 300 days/yr.

Annual electrical energy consumption values for each component were developed utilizing the technical literature and equipment manufacturers' specifications. In developing the costs, all electric motors were assumed to have an efficiency of 88 percent and the cost of electricity was assumed to be 3.3 cents/kwh. This cost value is an average value for the entire U.S. taken from the industry data collection portfolio responses.

Fuel oil and natural gas costs were also developed from a representative cross-section of the data collection portfolio responses and applicable technical literature. National average costs were determined to be 24 cents/therm for fuel oil and 18 cents/therm for natural gas.

Vacuum filtration energy consumption varies with filter area. The area, or size of the filter, is dependent on the amount of sludge to be dewatered which itself is a function of the chemical precipitation and filtration systems, and of the flow rate being evaluated. Consequently, energy consumption is dependent on these criteria also.

Energy consumption for activated carbon is dependent on the flow and whether the exhausted carbon is regenerated or discarded. The remaining technologies' consumption is based solely on flow.

Sludge Disposal. In the cost development and economic impact analysis, sludges from this industry were assumed to be nonhazardous. However, costs were developed late in the program for hazardous waste disposal. Based on comments it receives, the Agency will consider incorporation of these costs into the economic impact analysis.

For primary smelters and refiners, sludge disposal costs cover hauling dewatered sludge, exhausted activated carbon, and concentrated reverse osmosis brine, when applicable, to an approved sanitary landfill. These sludges may be disposed of in this fashion since wastes generated by primary smelters and refiners are currently exempted from regulation as hazardous waste by an act of Congress (Resource Conservation and Recovery Act (RCRA), Secton 3001(b)). The hauling costs for these wastes were obtained from the literature, and plotted as tons/yr of dry sludge hauled vs. $/dry ton. A round trip hauling distance of 10 miles was assumed. These costs are depicted in Figure VIII-3.

For secondary smelters and refiners, no such exemption currently applies, i.e., waste generated by secondary metals operations is subject to designation as hazardous waste based on its toxicity, ignitability, corrosivity, or reactivity. Costs for disposal by sludge hauling of nonhazardous waste are found in Figure VIII-3; costs for disposal of hazardous wastes were calculated depending upon the disposal method selected.

Several potentially hazardous wastes, such as furnace slags, skimming slags, and scrap preparation solids, may be disposed of in ground sealed dump areas. Capital costs for this method include sealing, collection ditches, and pumps and piping. Operation and maintenance costs are estimated at 5 percent of the capital cost. The investment cost as a function of slag output is presented in Figure VIII-4.

Wastewater treatment sludges, reverberatory furnace solids, neutralized spent battery electrolyte (from secondary lead operations), and other waste may be disposed of on-site in lined or unlined disposal ponds, or by contract hauling. The capital costs for the impoundment method include pond excavation and diking, liner (as necessary), and monitoring wells and equipment. Direct operating costs were estimated at 8 percent of the capital cost, and largely consisted of maintenance, taxes, and insurance. The capital costs for this method are presented in Figure VIII-5.

Contract hauling costs for hazardous sludges and solid waste are a function of the distance to the disposal site, the costs incurred by the hauler to meet the RCRA requirements for transportation of hazardous materials, and the disposal site costs. Figure VIII-6 displays the transportation costs for hazardous sludges, based on a 20 to 25 ton shipment. These costs should be combined with the appropriate contract hauling costs presented in Table VIII-1. Costs are tabulated for disposal of sludge (i.e., greater than 5 percent free liquid) in 55-gallon drums or in bulk shipment, and for solids (i.e., less than 5 percent free liquid) in bulk shipment.

Casting lubricants consist of oil-water mixtures that are often emulsified. In some cases these lubricants may represent a hazardous material. Costs for separation of the oil and water fraction are presented in Figure VIII-7. Capital costs include a staged mixer-settler, with addition of a flocculant or de-emulsifier. Direct operating costs are estimated at 40 percent of the capital cost, of which approximately 75 percent is labor-related. The oil separated in the settler may be contract hauled or sold.

Sludge disposal costs are included for technology options using chemical precipitation and sedimentation with and without filtration, activated alumina, activated carbon, and reverse osmosis. The sludge generation assumptions and factors are discussed within each module description below.

Monitoring. The costs are based on collecting samples of the influent and effluent streams of the treatment plant. The sampling schedule is for 24-hour composite samples to be taken once per week. Continuous monitoring of the pH and flow is also provided for the influent and effluent of all treatment plants.

The equipment items include two flow meters, two primary and one backup refrigerated samplers, two pH meters, refrigerated sample storage containers, and a refrigerator. The costs are based on equipment manufacturers' price lists. The annual labor requirements for laboratory work range from 40 hours at 0.01 mgd to 3,500 hours at 20 mgd.

Monitoring costs include outside laboratory analytical charges and time for reporting results to regulatory agencies. The costs associated with collecting and delivering samples are included under operation and maintenance labor.

Sampling frequency was assumed to be once per week of both the influent and effluent. Criteria pollutants (conventional and nonconventional pollutants) are analyzed once per week and priority pollutants are analyzed once per month.

Laboratory cost estimates were June, 1978 commercial laboratory price lists. Reporting costs were based on $15/hr and included 2 hr/week for compiling data plus 8 hr/month for preparing reports.

TECHNOLOGY BASIS FOR COST DEVELOPMENT

The treatment alternatives considered as the basis for BPT and BAT limitations consist of in-process control steps and end-of-pipe treatment technologies. The following subsections present the elements of each control and treatment step for which costs were prepared. These include:

--Recycle
--Steam Stripping
--Cyanide Precipitation
--Primary Sedimentation
--pH Adjustment
--Chemical Precipitation, Sedimentation, Gravity Thickening, Vacuum Filtration
--Multimedia Filtration
--Activated Carbon Adsorption
--Activated Alumina Adsorption
--Reverse Osmosis, Evaporation

Recycle

The in-plant control measures that exist in or are available to plants in the nonferrous metals category are discussed in Section VII of the supplements. The incorporation of in-plant controls into the processes of an existing source can be a cost-effective means of reducing pollutant and hydraulic loadings and thereby the cost of treatment facilities. Recycle of various process streams is the most common in-plant control suggested for BAT. A description of the recycled streams is provided in Section VIII of each supplement, and the costs of the recommended in-plant controls are included for each treatment scheme in the summation curves of annual costs. In some cases, the costs associated with equipment installed to provide flow reduction are presented separately from the summation curves.

Holding tanks or a cooling tower are the principal cost elements for recycle or reuse of certain plant wastewaters. These two items will be discussed together as they are incorporated into the various treatment schemes to provide flow reduction through recycle. A cooling tower is costed for reduction of flow from casting contact cooling water, and holding tank(s) is costed for reduction of flow from wet air pollution control equipment.

The investment costs for a holding tank include tanks, pumps, and 1,000 ft of piping with the tanks sized to store one day of flow. There are no operation and maintenance costs associated with a holding tank. The investment costs for a cooling tower assume the use of a mechanical draft tower and include the tower, pumps, 305 meters (1,000 ft) of piping, fans and packing. The sizing of the tower is based on a range of 13.9°C (25°F), an approach (driving force) temperature of 5.6°C (10°F), and a wet bulb temperature of 21.11°C (70°F). The O&M labor requirements varied from 82 hr/yr at 0.6 mgd to 1,340 hr/yr at 20 mgd. Maintenance materials were assumed as 3 percent of the installed cost. Energy requirements are for the forced draft fans, which vary from 1.7 hp at 0.1 mgd to 200 hp at 10 mgd.

Steam Stripping

A stripping tower and steam are used to remove ammonia from the wastewater. The investment costs include a stripping tower, a boiler, and a blower. A surface loading rate of 81.5 $l/min\text{-}m^2$ (2 gpm/ft^2) was assumed along with a steam requirement of 1 pound of steam per gallon of wastewater treated.

O&M labor requirements ranged from 21 hr/yr at .1 mgd to 1,330 hr/yr at 20 mgd. Maintenance materials were assumed at 3 percent of the investment cost. Costs for steam, electrical requirements, and chemicals were also included.

Cyanide Precipitation

In this wastewater treatment technology, cyanide is reacted with ferrous (or zinc) sulfate in the presence of H_2SO_3 and then raised to pH 9.0 to form a variety of precipitates that may best be represented as $Fe_4(FeCN_6)_3$ (Prussian Blue). This system, which closely resembles a conventional chemical precipitation operation, includes chemical feed equipment for sodium hydroxide and ferrous sulfate addition, a reaction vessel, agitator, control system, clarifier, and pumps.

Costs are estimated for both batch and continuous systems with the operating mode selected on a least cost basis. This decision is a direct function of flow rate. Capital costs are composed of five subsystem costs: (1) $FeSO_4$ feed system, (2) NaOH feed system, (3) reaction vessel with agitator, (4) clarifier, and (5) recycle pump. These subsystems include the following equipment:

(1) Ferrous sulfate feed system

- ferrous sulfate steel storage hoppers with dust collectors (largest hopper size is 6,000 ft^3; 15 days storage)
- enclosure for storage tanks
- volumetric feeders (small installations)
- mechanical weigh belt feeders (large installations)
- dissolving tanks (5 minute detention time, 6 percent solution)
- dual-head diaphragm metering pumps
- instrumentation and controls

(2a) Caustic feed system (less than 200 lb/day usage)

- volumetric feeder
- mixing tank with mixer (24-hour detention, 10 percent solution)
- feed tank with mixer (24-hour detention)
- dual-head metering pumps
- instrumentation and controls

(2b) Caustic feed system (greater than 200 lb/day usage)

- storage tanks (15 days, FRP tanks)
- dual-head metering pumps including standby pump
- instrumentation and controls

(3) Reaction tank (5 minutes detention time, stainless steel, agitator mounting, agitator, concrete slab)

(4) Clarifier tank (based on 700 gpd/ft^2; to include a steel or concrete vessel (depending on flow rate), support structure, sludge scraper assembly and drive unit)

(5) Recycle pumps (for sludge and supernatant)

Operation and maintenance costs for cyanide precipitation include labor requirements to operate and maintain the system, electric power for mixers, pumps, clarifier and controls, and treatment chemicals. Electrical requirements are also included for the chemical storage enclosures for lighting and ventilation and in the case of caustic storage, heating. The following criteria are used in establishing O&M costs.

(1) Ferrous sulfate feed system

- maintenance materials - 3 percent of manufactured equipment cost
- labor for chemical unloading
  --5 hr/50,000 lb for bulk handling
  --8 hr/16,000 lb for bag feeding to the hopper
  --routine inspection and adjustment of feeders is 10 min/feeder/shift
- maintenance labor
  --8 hr/yr for liquid metering pumps
  --24 hr/yr for solid feeders and solution tank
- power (function of instrumentation and control, metering pump hp and volumetric feeder (bag feeding))

(2) Caustic feed system

- maintenance materials - 3 percent of manufactured equipment cost (excluding storage tank cost)
- labor/unloading
  --dry NaOH - 8 hr/16,000 lb
  --liquid 50 percent NaOH - 5 hr/50,000 lb
- labor operation (dry NaOH only) - 10 min/day/feeder
- labor operation for metering pump - 15 min/day
- annual maintenance - 8 hr
- power (includes metering pump hp, instrumentation and control, volumetric feeder (dry NaOH))

(3) Clarifier

- maintenance materials range from 0.8 percent to 2 percent as a function of increasing size
- labor - 150 to 500 hr/yr (depending on size)
- power - based on horsepower requirements for sludge pumping and sludge scraper drive unit

(4) Reaction vessel with agitator

- maintenance materials - 2 percent of equipment cost
- labor
  --15 min/mixer/day routine O&M
  --4 hr/mixer/6 mos - oil changes
  --8 hr/yr - draining, inspection, cleaning
- power - based on horsepower requirements for agitator

(5) Recycle pump

- maintenance materials - percent of manufactured equipment cost variable with flow rate
- 50 ft TDH; motor efficiency of 90 percent and pump efficiency of 85 percent

Annual costs for treatment chemicals are determined from cyanide concentration, pH, metals concentrations, and flow rate of the raw waste stream.

pH Adjustment

H_2SO_4 (66° Be') or NaOH (50 percent NaOH) are utilized to obtain desired pH values at various points in any given alternative sequence. The investment costs include:

(1) Chemical feed system

- bulk storage tank
- dry tank
- mixer
- flow regulator

(2) Concrete tank (detention time, 15 minutes)

(3) Mixing equipment

(4) Instrumentation

(5) Sump pump

Operating costs are based on the following assumptions:

(1) Sulfuric acid dose rate of 0.5 pound per 1,000 gallons of wastewater.

(2) Caustic dose rate of 0.5, 5, and 20 pounds per 1,000 gallons of wastewater.

Labor and energy costs were assumed to be equal for all alkali and acid dose rates. Energy requirements on a system basis are linear from 10,000 gal/day at 660 Kw-hr/yr and increase to 14,000 Kw-hr/yr at 10 mgd.

Chemical Precipitation, Sedimentation, Gravity Thickening, Vacuum Filtration

This process is used to remove dissolved metals as metal hydroxides. Precipitation occurs through addition of lime ($Ca(OH)_2$) to the wastewater; the hydroxides are removed by settling in a sedimentation device, usually a clarifier. The overflow is routed to further treatment or discharged while the underflow sludge is sent to sludge dewatering in a vacuum filter, sometimes preceded by concentration in a sludge thickener.

Lime was selected as the precipitant because of its comparatively low cost coupled with its proven effectiveness in the category. While it is recognized that caustic, iron salts, and sulfides may be more appropriate in some applications, costs for these precipitants and feed systems are comparable to the lime-based system relative to the overall costs of a chemical precipitation unit.

The equipment included in this system is as follows:

(1) Lime feed system

  - storage units (30 days storage)
  - dilution tanks (slaker as necessary)
  - metering pumps

(2) Rapid mix tank and agitator (5 minutes detention time)

(3) Clarifier (hydraulic loading rate of 0.5 gpm/ft^2)

  - concrete or steel
  - sludge rake

(4) Gravity thickener

(5) Vacuum filter

  - motor and drive
  - piping and pumps
  - vacuum system
  - rotary filter (4 lb/hr/ft^2)

(6) Auxiliaries

(7) Control system

To specify lime dosages, specific model wastewater matrices (or cases) were developed from examination of untreated wastewater data in the industry. The lime dosages for the various waste stream combinations could be classified into the different cases based on the lime requirements for each component stream, which in turn were calculated from the concentrations of pollutants in the stream that consume lime. These lime dosages will also affect the amount of sludge produced from the system. The cases, lime dosages, and sludge generation factors are presented in the following tabulation:

Case	Lime Dosage (mg/l)	Sludge (lb/mil gal)
1	16,000	500,000
2	7,300	250,000
3	2,500	100,000
4	1,100	50,000
5	580	25,000
6	285	10,000
7	50	1,500

Units were sized for these cases based on an overflow rate of 40.75 m^3/day-m^2 (1,000 gpd/ft^2) for sedimentation and an application rate of 122 kg/day-m^2 (25 lb/ft^2/day) for gravity thickening. O&M labor requirements for lime precipitation and sedimentation vary from 1,450 hours at 0.01 mgd to 4,950 hours at 20 mgd.

The investment costs for vacuum filtration were developed in terms of the amount of sludge to be dewatered. The sludge generation factors listed on the preceding table are exclusive of multimedia filtration backwash solids and other sludges produced in the treatment system but dewatered on the vacuum filter. The extra capacity required to handle these sludges is calculated for each sludge-generating module, so that the vacuum filter is adequately sized. The generation of these other sludges is described in the appropriate module discussion. The filter area was calculated using a dry solids loading rate of 19.53 kg/m^2/hr (4 lb/ft^2/hr) and an operating period of 10 hrs/day.

O&M labor requirements for vacuum filtration vary from 1,635 manhours at 0.01 mgd to 29,100 manhours at 10 mgd.

Multimedia Filtration

Multimedia filtration is used as a wastewater treatment polishing device to remove suspended solids not removed in previous treatment processes. The filter beds consist of graded layers of gravel, coarse anthracite coal, and fine sand. The equipment used to determine capital and annual costs follow:

1. Filter tank and media
2. Surface wash system
3. Backwash system
4. Valves
5. Piping
6. Controls
7. Electrical system

The hydraulic loading rate used was 163 $l/min\text{-}m^2$ ($4\ gpm/ft^2$). Specific cases were developed for filtration as follows:

Case	TSS Removed (mg/l)
1	100
2	50
3	15
4	5

The solids carried over to the filter from chemical precipitation have a direct influence on the solids being recycled in the backwash to the secondary clarifier and therefore add to the sludge volume applied to the vacuum filter. The additional sludge was accounted for in each case by multiplying the TSS removed by the flow rate. For options where multimedia filtration is included, the extra capacity required for the vacuum filter to dewater the backwash solids was included.

O&M labor requirements vary from 45 manhours at 0.01 mgd to 3,400 manhours at 20 mgd.

Activated Carbon Adsorption

Activated carbon is used primarily for the removal of organic compounds from wastewater. The capital and annual costs for this process are based on a system using granular activated carbon (GAC) in a series of downflow contacting columns.

The effectiveness of activated carbon in removing the organic priority pollutants has not yet been demonstrated in the nonferrous metals category. Reports are available, however, that discuss the degree of adsorbability of activated carbon for the individual priority toxic organics. Based upon these reports, conservative estimates have been made for removals by carbon and its exhaustion rates under different operating conditions. An exhaustion rate of .18 kg/m^3 (1,500 lb/mil gal) was assumed for all subcategories except secondary silver. A .66 kg/m^3 (5,500 lb/mil gal) and 1.49 kg/m^3 (12,400 lb/mil gal) exhaustion rate was assumed for secondary silver, nonphotographic and photographic unit processes, respectively.

Two methods of replacing spent carbon were considered: (1) thermal regeneration of spent carbon and (2) replacement of spent carbon with new carbon and disposal of spent carbon. Thermal regeneration of spent activated carbon is economically practical only at relatively large carbon exhaustion rates. Simply replacing spent carbon with new carbon is more practical than thermal regeneration for plants with low carbon usage.

An economic analysis was performed to determine the carbon usage rate at which thermal regeneration of spent carbon becomes practical. It was determined that thermal regenerating facilities are practical above a carbon usage of 105,000 kg/yr (230,000 lbs/yr). Plants not regenerating carbon on-site were assumed to dispose of the spent carbon using the exhaustion rates described above. Plants for which regeneration would occur on-site were assumed to generate no carbon wastes to be disposed.

Thermal regeneration is assumed to be accomplished with multiple hearth furnaces at a loading rate of 40 pounds of carbon per square foot of hearth area per day. Activated carbon thermal regeneration facilities include a multiple hearth furnace, spent carbon storage and dewatering equipment, quench tank, screw conveyors, and regenerated carbon refining and storage tanks.

A 30-minute empty-bed contact time was used to size the downflow contacting units. The activated carbon used in the columns was assumed to have a bulk density of 26 pounds per cubic foot. Included in the capital for a carbon contacting system are carbon contacting columns, initial carbon fill, carbon inventory and storage backwash system, and wastewater pumping.

O&M labor requirements are dependent upon whether carbon is regenerated. In the adsorption only case, annual manhour requirements vary from 100 at 0.1 mgd to 4,700 at 20.0 mgd. If carbon is regenerated, annual manhour requirements vary from 140 at 0.01 mgd to 17,500 at 20 mgd. The activated carbon process incurs chemical costs for the replacement of carbon. For small plants that find it more economical to discard the carbon after exhaustion, the entire carbon inventory is replaced according to the exhaustion rate. For those plants that utilize on-site regeneration, it was assumed that 8 percent of the carbon is lost during each regeneration and must be replaced.

Activated Alumina Adsorption

Contact columns containing alumina are used to remove arsenic and fluoride. The backwash and spent regenerant are both recycled to the chemical precipitation unit for removal of the concentrated pollutants.

The investment costs are based on a system using activated alumina in contacting columns, acid and caustic feed systems, a control system, and pumping and piping. A surface loading rate of 122 $l/min\text{-}m^2$ (3 gpm/ft^2) was assumed with an alumina adsorption capacity of 0.5 percent by weight for fluoride and arsenic.

Activated alumina manpower requirements are based on activated carbon and ion exchange labor requirements. The values vary from

210 manhours per year at 0.01 mgd to 5,200 manhours per year at 20 mgd. Activated alumina chemical usage includes sulfuric acid (66° Be') and sodium hydroxide (50 percent NaOH) for regeneration, and replacement of activated alumina. For regeneration, four bed volumes of 1 percent NaOH and one bed volume of .05N H_2SO_4 are needed every two days. A replacement rate of 10 percent per year for activated alumina was assumed.

Reverse Osmosis, Evaporation

To remove selected ions from the wastewater streams, a reverse osmosis unit with prefiltration cartridges is used. The resulting brines are further concentrated into a disposable sludge by multiple-effect evaporators.

The equipment in this module includes:

1. Holding tank
2. Prefiltration cartridge
3. Membranes
4. Membrane housing
5. Feed and brine pumps
6. Mechanical evaporation system
7. Instrumentation and control system

Costs were based on a recovery of 85 percent of the flow through the reverse osmosis unit at 600 psi, a 95 percent solids rejection rate, and a 98 percent reduction in the brine flow through the mechanical evaporator. The brine is evaporated to 25 percent solids, which is contract hauled.

The reverse osmosis labor requirements varied from 7,300 manhours per year at 0.6 mgd to 22,000 manhours per year at 20 mgd. Maintenance items include the membranes, which were assumed to have a 2-year life. Energy requirements include steam for evaporation and electricity for the pumps.

NEW SOURCES

The technology options considered for new sources are identical to those considered for existing sources. Additional flow reduction is being proposed for primary aluminum based on the elimination of wet scrubbers in this subcategory, and for the primary lead subcategory based on the elimination of slag granulation, since the use of dry scrubbers and slag dumping is currently demonstrated at several plants in the affected subcategories. EPA assumes, therefore, that the application of these technologies in some existing plants is based on a determination that any incremental cost of these technologies over other practices is offset by savings in end-of-pipe treatment costs or specific manufacturing costs.

COST METHODOLOGY FOR SPECIFIC PLANTS

The capital and operating costs for each treatment option are used to analyze the economic impact of the proposed regulations on each subcategory (see Economic Impact Analysis for Effluent Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category, EPA, 1983). The approach used is to estimate the compliance costs for each plant in the subcategory, accounting for the specific combination of wastewaters, the wastewater flow, and the existing treatment system at the plant.

These plant-specific cost estimates for the nonferrous metals category were developed over an extended time period during which several changes in the approach to regulation of the category have been made. The cost estimation procedure reflects these changes.

First, amortization of the capital investment was originally assumed to be based on a 7.75 percent interest rate over a 20-year period. Although costs presented in the curves in each supplement reflect these assumptions, updated values of 10 percent interest over 10 years were used for the specific plant costs in the economic impact analysis. The revised amortization interest rate and period will also be reviewed and updated as necessary before final promulgation of the regulation.

Second, the Agency originally chose to use actual wastewater flows in the sizing and costing of cooling towers to treat contact cooling water prior to recycle. Similarly, actual flows were also used to size and cost holding tanks to treat wet air pollution control wastewater prior to recycle. As a result, the estimated costs may be high for some plants. The Agency is currently considering the use of regulatory flows in sizing this equipment, i.e., a cooling tower or holding tank would be sized to handle the BPT regulatory flow for the appropriate wastewater. EPA requests comments on this approach.

NONWATER QUALITY ASPECTS

The elimination or reduction of one form of pollution may aggravate other environmental problems. Therefore, Sections 304(b) and 306 of the Act require EPA to consider the nonwater quality environmental impacts (including energy requirements) of certain regulations. In compliance with these provisions, EPA has considered the effect of this regulation on air pollution, solid waste generation, and energy consumption.

Air Pollution, Radiation and Noise

Various forms of both wet and dry air pollution control methods are utilized throughout the category. Replacement of wet systems by dry systems will reduce the pollutant loading discharged in the plant effluent. The alternatives for BAT presented in this document assume that those plants presently using wet air pollution control systems would not change to dry systems since retrofit costs would be high. As previously discussed, it is assumed that new sources will install dry systems instead of wet systems where dry systems have been demonstrated.

In general, none of the wastewater treatment or control processes causes air pollution. Steam stripping of ammonia has a potential to generate atmospheric emissions. With proper design and operation, however, air pollution impacts are eliminated. None of the wastewater treatment processes causes objectionable noise and none of the treatment processes has any potential for radiation hazards.

Solid Waste Disposal

As shown in the supplements, the waste streams being discharged contain large quantities of toxic and other metals; the most common method of removing the metals is by lime precipitation. Consequently, large volumes of heavy metal-laden sludge are generated that must be disposed of properly. Table VIII-2 summarizes the methods currently in use, along with their frequency of occurrence, for treating and disposing of sludges.

The technologies that directly generate sludge are:

1. Cyanide precipitation
2. Chemical precipitation
3. Multimedia filtration
4. Primary sedimentation
5. Reverse osmosis

Sludge is also indirectly generated by the recycling of the spent activated alumina regenerant, containing fluoride or arsenic, to the chemical precipitation unit. Spent carbon from activated carbon adsorption also represents a solid waste stream requiring disposal.

The sludge resulting from the five technologies listed above will vary in characteristics depending on the subcategory and combination of streams being treated. However, in most cases, the majority of the sludge produced is a result of chemical precipitation. This sludge will, in general, contain large quantities of precipitated metals. The sludge indirectly generated from activated alumina adsorption will contain large quantities of fluoride or arsenic.

A major concern in the disposal of sludges is the contamination of soils, plants, and animals by the heavy metals contained in the sludge. The leaching of heavy metals from sludge and subsequent movement through soils is enhanced by acidic conditions. Sludges formed by lime precipitation possess high pH values and thus are more resistant to acid leaching. Since the largest amount of sludge that results from the alternatives is generated by lime precipitation, it is not expected that metals will be readily leached from the sludge. Disposal of sludges in a lined sanitary landfill will further reduce the possibility of heavy metals contamination of soil, plants and animals.

Other methods of treating and disposing of sludge are available. Table VIII-2 shows that one method currently being used at a number of plants is reuse or recycle, usually to recover metals. Since the metal concentrations in some sludges may be substantial, it may be cost effective for some plants to recover the metal fraction of their sludges prior to disposal.

The Solid Waste Disposal Act Amendments of 1980 prohibited EPA from regulating certain wastes under Subtitle C of RCRA until after completion of certain studies and certain rulemaking. Among these wastes are "solid waste from the extraction, beneficiation and processing of ores and minerals." EPA has therefore exempted from hazardous waste status any solid wastes from primary smelting and refining, as well as from exploration, mining, and milling.

The Agency has not made a determination of the hazardous character of sludges and solid wastes generated from the secondary metals processing plants covered by this proposal. Each sludge generator in the secondary metals subcategories is subject to the RCRA tests for ignitability, corrosivity, reactivity, and toxicity. Costs for treatment and disposal of such sludges and solid wastes, as well as nonhazardous sludges and solid wastes, have been presented in this section.

Energy Requirements

The incremental energy requirements of a wastewater treatment system have been determined in order to consider the impact of this regulation on natural resource depletion and on various national economic factors associated with energy consumption. Based on the data collection portfolios, the median values for total plant energy consumption and wastewater flow rate were calculated for each subcategory. Within each subcategory, each treatment system option may vary somewhat depending on the wastewater combination being treated. For example, Option A in the primary tungsten subcategory includes steam stripping of ammonia only for discharges from specific unit operations.

Energy requirements were always calculated using the configuration for each option that would consume the most energy, i.e., the maximum energy requirement was always calculated.

Table VIII-3 presents these energy requirements in Kwh/yr for each subcategory and option. The percent increase in total plant energy requirements attributable to the treatment system is also presented on the table. Blanks appear in the table where that option was not relevant to that subcategory. By reviewing this table, it can be seen that the additional energy required is greater than 1 percent only for Option F (which includes reverse osmosis), and then only for certain subcategories. As a result, the Agency has concluded that the energy requirements of the proposed treatment options will not significantly affect the natural resource base nor energy distribution or consumption in communities where plants are located.

Table VIII-1

COSTS OF CONTRACT HAULING[2]

Type of Waste	Method of Shipment	$/Gal	$/Ton (Wet Basis) Percent Solids 10	20	30	$/Ton (Dry Basis)
Sludge Disposal	Drums - 55 Gallon	0.91	1,750	875	580	175[1]
	20-25 Ton Shipments	0.70	1,350	675	450	135[1]
Solids Disposal[3]	20-25 Ton Shipments					100

[1] Density = 78 lb/ft^3

[2] Does not include cost of transportation.

[3] Less than five percent free liquid.

Table VIII-2

EXISTING SLUDGE TREATMENT METHODS*

	Gravity Thickening	Vacuum Filter	Filter Press	Centri-fuge	Kiln Drying	Incin-eration	Calci-nation	Contractor Disposal	Drying Beds	Lagooning	Land-fill	Sale	Reuse/ Recycle
Primary Aluminum	7	5	1	0	1	2	1	1	1	13	11	1	5
Secondary Aluminum	7	2	0	0	0	0	0	1	1	4	6	1	0
Columbium/ Tantalum (Ore)	0	0	1	0	0	0	0	0	0	1	1	0	0
Columbium/ Tantalum (Salt)	1	0	0	1	0	0	0	0	0	0	0	0	1
Primary Copper (Smelters)	6	0	1	0	0	0	0	0	1	6	0	0	3
Primary Copper (Refiners)	3	0	1	0	0	0	0	1	0	3	2	0	0
Secondary Copper	4	2	1	1	0	0	0	0	0	3	6	3	4
Primary Lead	2	3	0	0	0	0	0	0	1	0	1	0	4

*Number of plants using sludge disposal and treatment methods.

Table VIII-2 (Continued)
EXISTING SLUDGE TREATMENT METHODS*

	Gravity Thickening	Vacuum Filter	Filter Press	Centri-fuge	Kiln Drying	Incin-eration	Calci-nation	Contractor Disposal	Drying Beds	Lagooning	Land-fill	Sale	Reuse Recycle
Secondary Lead	4	6	1	0	0	0	0	3	3	2	7	0	9
Secondary Silver (Photo)	3	2	2	0	0	2	0	1	0	0	0	5	4
Secondary Silver (Non-Photo)	2	1	0	2	0	0	0	2	4	2	2	0	4
Primary Tungsten (Ore)	2	3	2	0	0	0	0	0	0	1	2	1	0
Primary Tungsten (Salt)	1	0	0	0	0	0	0	0	0	1	0	1	1
Primary Zinc	3	3	0	1	0	0	0	1	1	1	3	1	2
TOTAL	45	27	10	5	1	4	1	10	12	37	41	13	37

*Number of plants using sludge disposal and treatment methods.

Table VIII-3

MAXIMUM ENERGY REQUIREMENT (Kwh/yr) AND ESTIMATED PERCENT OF PLANT TOTAL FOR ENTIRE TREATMENT SYSTEM

Subcategory	Total Plant Energy Consumption (Kwh/yr)	Median Size Plant by Flow (gpd)	Option A		Option B		Option C		Option D		Option E		Option F	
			Usage	Percent	Usage	Percent	Usage	Percent	Usage	Percent	Usage	Percent	Usage	Percent
Primary Aluminum	1.28×10^8	1,200,000	2.41×10^5	0.19	3.75×10^5	0.29	4.1×10^5	0.32	4.53×10^5	0.35*	1.05×10^6	0.82*	3.72×10^6	2.9
Secondary Aluminum	8.15×10^7	4,280	3.66×10^4	0.045			3.66×10^4	0.045					5.33×10^4	0.065
Primary Columbium-Tantalum	6.19×10^7	59,000	6.56×10^4	0.11	6.56×10^4	0.11	6.73×10^4	0.11	6.94×10^4	0.11	9.63×10^4	0.16	2.62×10^5	0.42
Primary Copper	2.55×10^8	1,640,000			3.87×10^5	0.15	3.9×10^5	0.15					6.50×10^5	0.25
Secondary Copper	3.35×10^{11}	7,600	1.64×10^4	0.05			1.66×10^4	0.05						
Primary Lead	2.30×10^8**	1,240,000											6.4×10^6	2.8
Secondary Lead	2.29×10^7	5,760	2.42×10^4	0.11	3.92×10^4	0.17	3.95×10^4	0.17	4.13×10^4	0.18			6.15×10^4	0.27
Secondary Silver	1.02×10^7	521	7.14×10^3	0.07	2.23×10^4	0.22	2.23×10^4	0.22			2.58×10^4	0.25		
Primary Tungsten	3.64×10^7	172,000	1.90×10^5	0.52	1.90×10^5	0.52	2.01×10^8	0.55			2.93×10^5	0.805	7.41×10^5	2.0
Primary Zinc	5.51×10^8	675,000			1.51×10^4	0.003	3.51×10^4	0.006	8.20×10^4	0.01			1.99×10^6	0.36

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*Option D and Option E correspond to Option D_1 and Option D_2 in the primary aluminum supplement.

**This is the energy consumption of the single discharger in the primary lead subcategory.

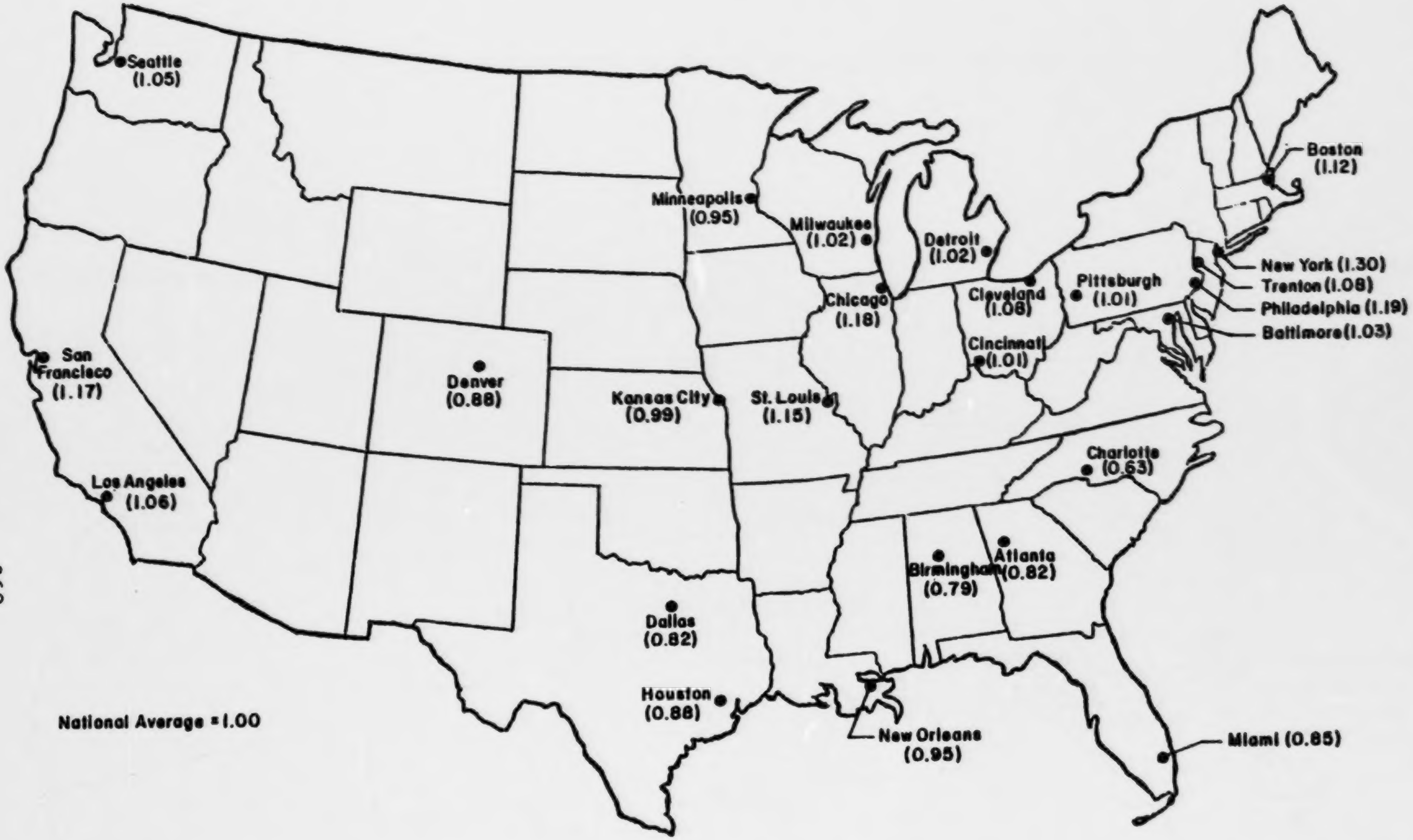

Seattle (1.05)
San Francisco (1.17)
Los Angeles (1.06)
Denver (0.88)
Minneapolis (0.95)
Milwaukee (1.02)
Detroit (1.02)
Chicago (1.18)
Cleveland (1.08)
Pittsburgh (1.01)
Cincinnati (1.01)
Kansas City (0.99)
St. Louis (1.15)
Boston (1.12)
New York (1.30)
Trenton (1.08)
Philadelphia (1.19)
Baltimore (1.03)
Charlotte (0.63)
Birmingham (0.79)
Atlanta (0.82)
Dallas (0.82)
Houston (0.88)
New Orleans (0.95)
Miami (0.85)
National Average = 1.00

Figure VIII-1

GEOGRAPHICALLY DISTRIBUTED CAPITAL COST FACTORS

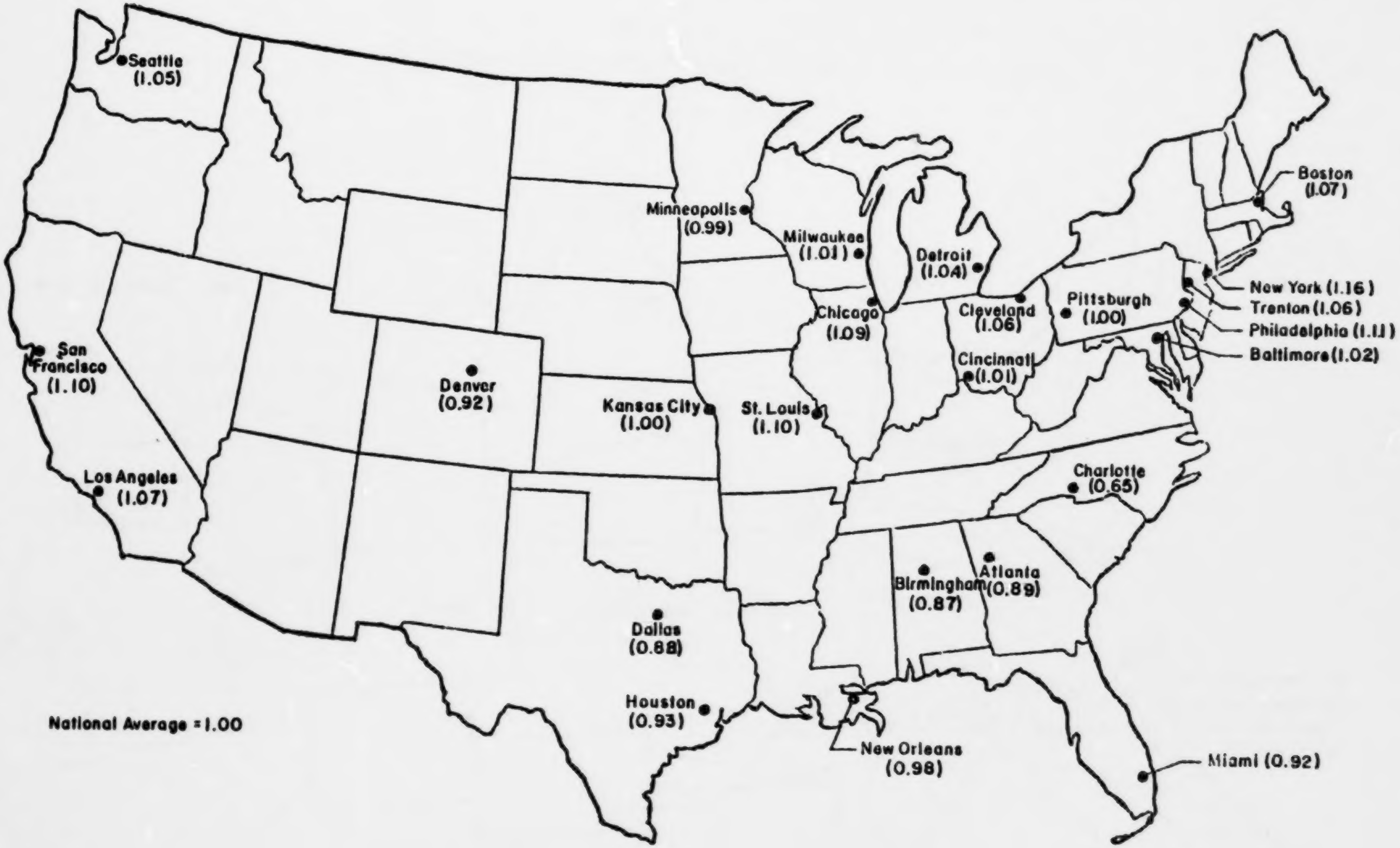

Seattle (1.05)
San Francisco (1.10)
Los Angeles (1.07)
Denver (0.92)
Minneapolis (0.99)
Kansas City (1.00)
Dallas (0.88)
Houston (0.93)
Milwaukee (1.01)
Chicago (1.09)
St. Louis (1.10)
New Orleans (0.98)
Detroit (1.04)
Cleveland (1.06)
Cincinnati (1.01)
Birmingham (0.87)
Atlanta (0.89)
Pittsburgh (1.00)
Charlotte (0.65)
Miami (0.92)
Boston (1.07)
New York (1.16)
Trenton (1.06)
Philadelphia (1.11)
Baltimore (1.02)
National Average = 1.00

Figure VIII-2

GEOGRAPHICALLY DISTRIBUTED WAGE RATE FACTORS

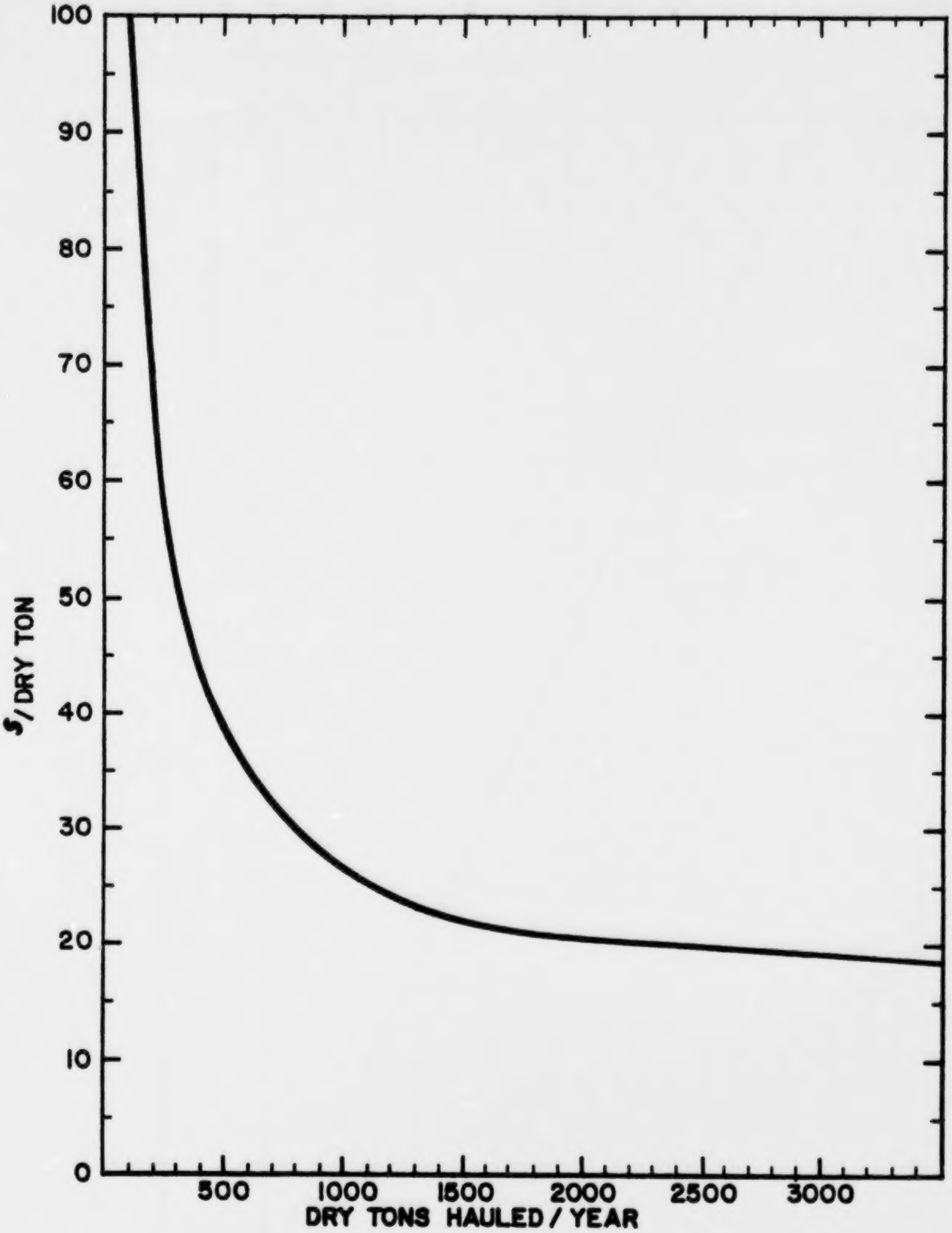
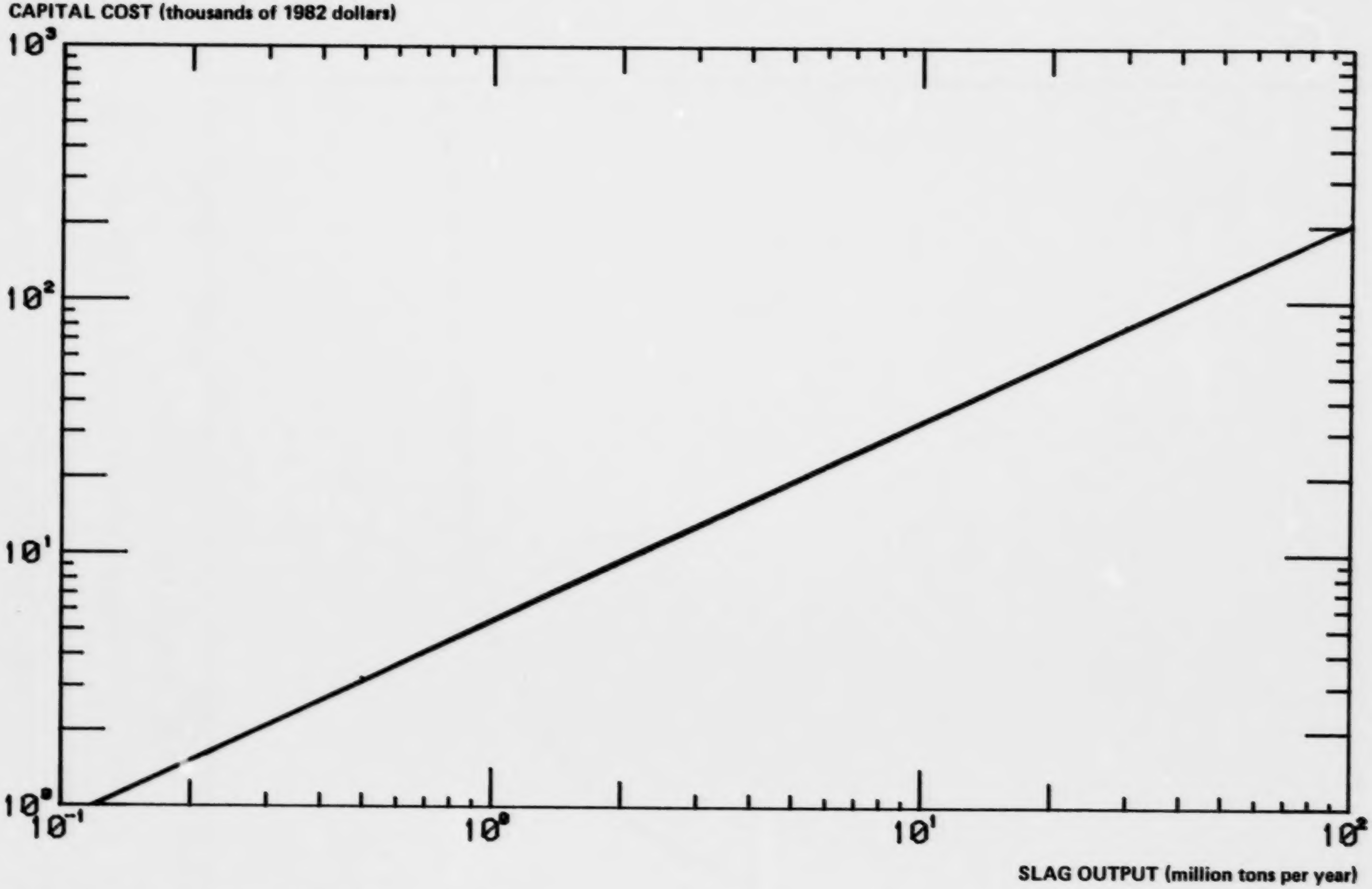


Figure VIII-3

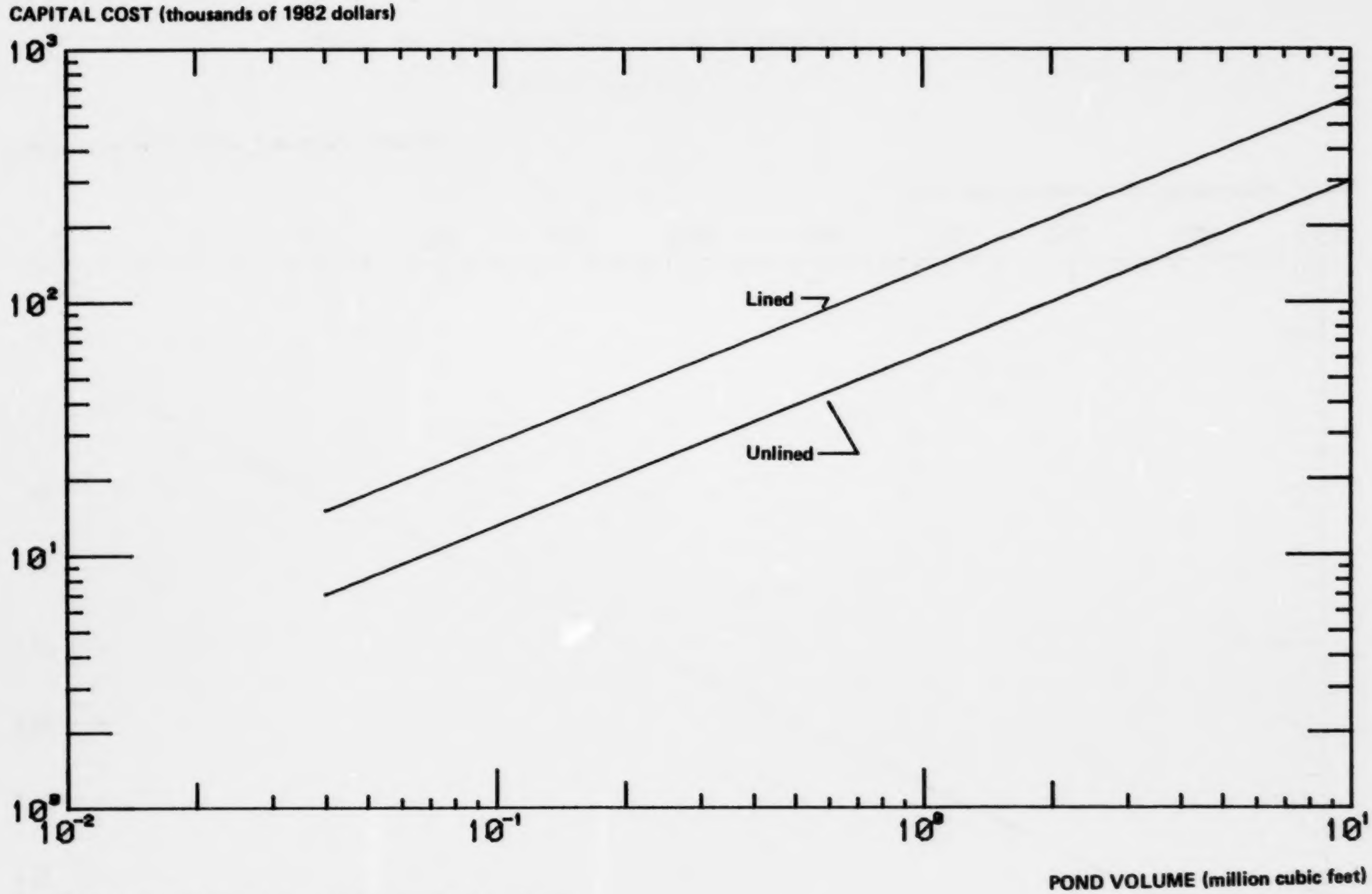
SLUDGE HAULING COSTS
10 MILE ROUND TRIP
NONHAZARDOUS WASTES



NOTE: Direct operating cost is equal to 5 percent of capital cost.

Figure VIII-4

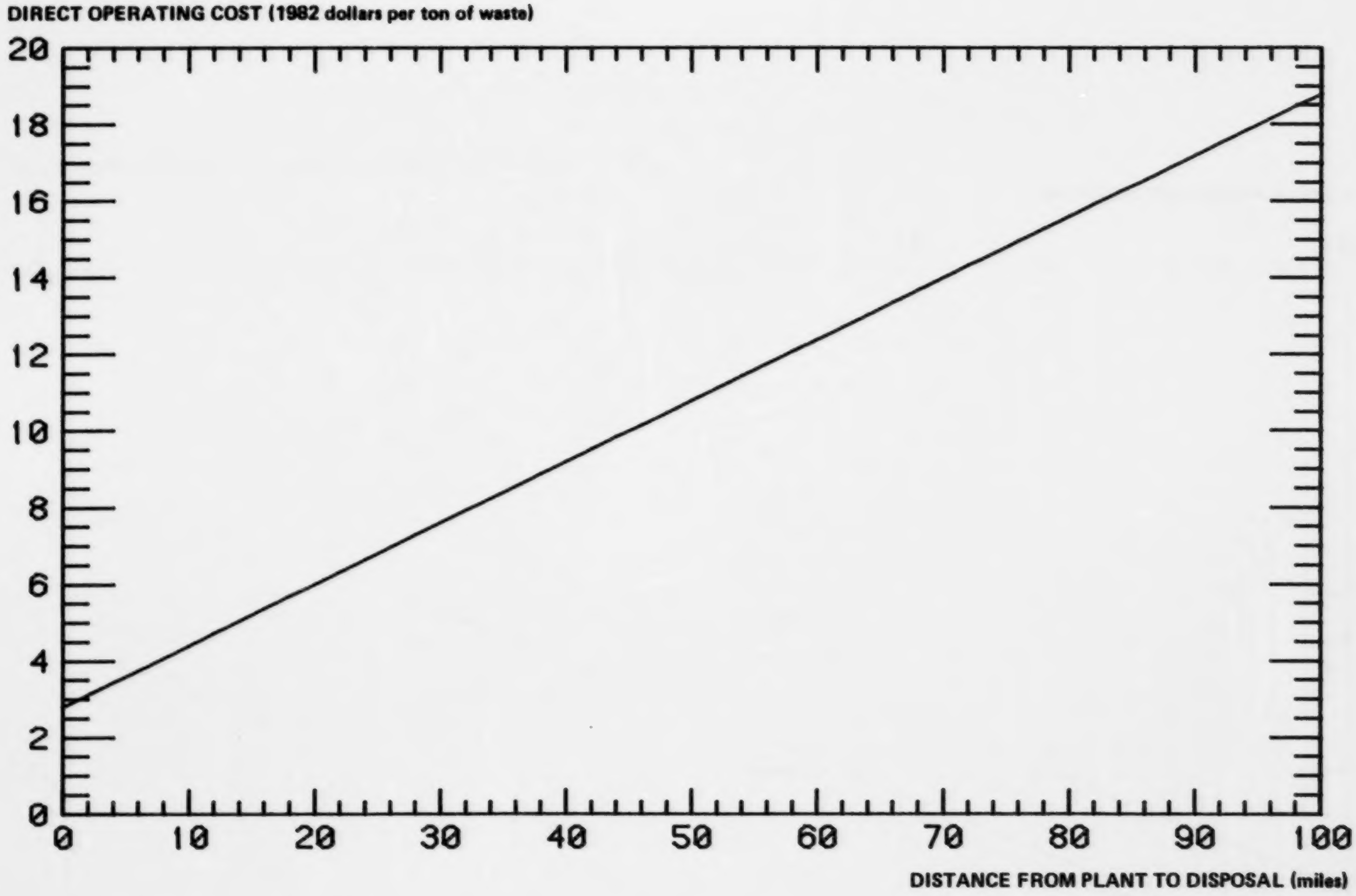
COST OF SEALING GROUND AT SLAG DUMP



NOTE: Direct operating cost is equal to 8 percent of capital cost

Figure VIII-5

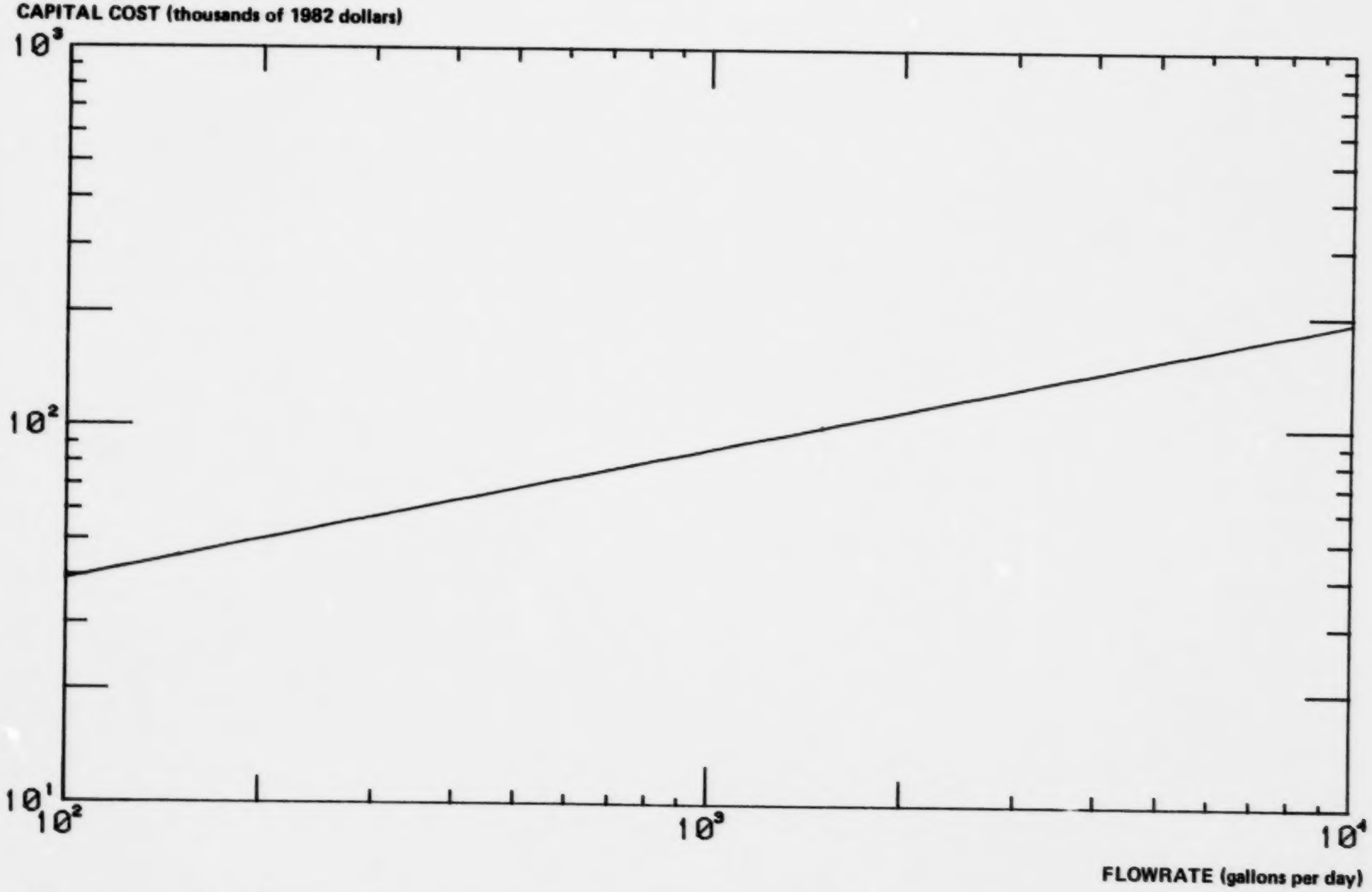
COST OF LINED AND UNLINED STORAGE PONDS



NOTE: Costs are based on 20 to 25 ton shipment.

Figure VIII-6

COST OF TRANSPORTING WASTE MATERIALS



NOTE: Direct operating cost is equal to 40 percent of capital cost.

Figure VIII-7

COST OF OIL SEPARATION

SECTION IX

EFFLUENT QUALITY ATTAINABLE THROUGH APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

This section sets forth the effluent limitations attainable through the application of best practicable control technology currently available (BPT). It also serves to summarize changes from previous rulemakings in the nonferrous metals manufacturing category, and presents the development and use of the mass-based effluent limitations.

A number of considerations guide the BPT analysis. First, effluent limitations based on BPT generally reflect performance levels achieved at plants in each subcategory equipped with the best wastewater treatment facilities. The BPT analysis emphasizes treatment facilities at the end of a manufacturing process but can also include in-plant control techniques when they are considered to be normal practice within the subcategory. Finally, the Agency closely examines the effectiveness of the various treatment technologies by weighing the pollutant reduction benefits achievable by each treatment alternative and assesses the installation and operational costs to enable it to determine the economic achievability of each option.

The limitations are organized by subcategory, i.e., limitations are presented by subcategory in Section II. The limitations were developed based on the sampling, treatability, and cost data that have been presented in this document. The analysis has resulted in a number of modifications to existing BPT effluent limitations.

TECHNICAL APPROACH TO BPT

In the past, the technical approach for the nonferrous metals manufacturing category considered each plant as a single wastewater source, without specific regard to the different unit processes that are used in plants within the same subcategory. This approach is appropriate for BPT which is generally based upon end-of-pipe technology. In-process controls are generally not used to establish BPT; however, they may be used as the basis of BPT when they are widely demonstrated in the category. In reevaluating the existing BAT regulations and developing new BAT regulations, the Agency closely examined each process and the potential for implementing in-process controls. It became apparent that it was best to establish effluent limitations and standards recognizing specific waste streams associated with specific manufacturing operations. This also results in more effective pollution abatement by tailoring the regulation to reflect these various wastewater sources. Currently promulgated

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BPT effluent limitations using this approach will not be modified unless there is sufficient data supplied to the Agency demonstrating the need for change.

This approach, referred to as the building block approach, establishes pollutant discharge limitations for each source of wastewater identified within the subcategory. Each wastewater source is allocated a discharge based on the average reported discharge rates for that source. These flows are normalized (related to a common basis) using a characteristic production rate associated with the wastewater source (volume of wastewater discharged per unit mass of production). The mass limitations established for a wastewater source are obtained by multiplying the effluent concentrations attainable by the selected BPT technology by the regulatory flow for each wastewater source. Thus, the specific pollutant discharge allowances for a plant's final discharge permit are calculated by multiplying the appropriate production rates with the corresponding mass limitations for each wastewater source in that plant, and then summing the results. This calculation is performed to obtain the one-day and the maximum monthly average limitations. It is important to note that the plant need only comply with the mass limitations and not the flow allowances or concentrations. In cases where process and nonprocess wastewater sources not specifically regulated by this proposal exist within the facility, the permit authority must treat these on a case-by-case basis.

Although each waste stream may not include each selected pollutant, a discharge allowance is provided for all pollutants in every waste stream because each waste stream contributes to the total loading of a combined waste treatment system. Since a discharge allowance is included for each pollutant in every waste stream, facilities would not be required to reduce pollutant concentrations below the performance limits of the technology. Instead, this approach allows plants to achieve the performance determined for the technology at the plant discharge point. Therefore, the mass limitations used are the product of the concentration achievable by the technology and basis of the limitation and the sum of regulatory flows for each unit process actually operated at the plant.

In determining the technology basis for BPT, the Agency reviewed a wide range of technology options and selected six alternatives which could be applied to nonferrous metals manufacturing as BPT options. These options include:

1. Option A - End-of-pipe treatment consisting of lime precipitation and clarification, and preliminary treatment, where necessary, consisting of oil skimming, cyanide precipitation, and ammonia steam stripping. This combination of technology reduces toxic metals and conventional pollutants.

2. Option B - Option B is equal to Option A preceded by flow reduction of process wastewater through the use of cooling towers for contact cooling water and holding tanks for all other process wastewater subject to recycle.

3. Option C - Option C is equal to Option B plus end-of-pipe polishing filtration for further reduction of toxic metals and TSS.

4. Option D - Option D is equal to Option C plus treatment of isolated waste streams with activated carbon adsorption for reduction of toxic organics and activated alumina for reduction of fluorides and arsenic concentrations.

5. Option E - Option E consists of Option C plus activated carbon adsorption applied to the total plant discharge as a polishing step to reduce toxic organic concentrations.

6. Option F - Option F consists of Option C plus reverse osmosis treatment to attain complete recycle of all process wastewater.

A combination of these options was examined for each subcategory based on the concentration of pollutants found in raw wastewaters of each subcategory. For example, toxic organic pollutants were not found above treatable concentrations in the primary lead subcategory. Therefore, treatment Options D_2 and E, which contain activated carbon adsorption, were not considered. For each of the selected options, the mass of pollutant removed and the costs associated with application of the option were estimated. A description regarding the pollutant reduction benefits associated with the application of each option is presented in Section X, while the cost methodology is presented in Section VIII.

MODIFICATIONS TO EXISTING BPT EFFLUENT LIMITATIONS

Prior to this rulemaking session, BPT effuent limitations have been promulgated for eight of the 12 nonferrous manufacturing subcategories:

1. primary aluminum smelting,
2. secondary aluminum,
3. primary copper smelting,
4. primary electrolytic copper refining,
5. secondary copper,
6. primary lead,
7. primary zinc, and
8. metallurgical acid plants.

At this time, four new subcategories are proposed for inclusion in the nonferrous metals manufacturing point source category. There have been no previous effluent limitations developed for these four subcategories listed below:

1. primary tungsten,
2. primary columbium-tantalum,
3. secondary silver, and
4. secondary lead.

It is not EPA's intention to modify effluent limitations promulgated in previous rulemakings unless new information warrants change. As such, EPA is proposing to modify BPT effluent limitations for the primary lead subcategory in light of new information submitted to the Agency. EPA is proposing that the metallurgical acid plants subcategory be modified to include acid plants associated with primary zinc and primary lead. In addition, modifications are proposed for existing stormwater exemptions promulgated in the primary lead subcategory.

PRIMARY LEAD

The currently promulgated BPT for this subcategory is based on the complete recycle and reuse of slag granulation wastewater (or dry slag dumping), dry air scrubbing, and treatment and impoundment (subject to allowances for net precipitation and catastrophic precipitation events) of acid plant blowdown. As mentioned earlier, acid plant blowdown is now included in the metallurgical acid plants subcategory. This suggests that BPT for primary lead should be zero discharge. Since promulgation, however, additional data collected by the Agency supports the need for discharge of wastewater from slag granulation. Although it was previously thought that slag granulation is a net water consuming operation, the additional data show that at least one plant uses an ore with a lead content sufficient to justify recycling blast furnace slag into the sintering machine to recover the remaining lead content. For this reason, EPA is proposing modification of promulgated BPT for this subcategory to allow a discharge from slag granulation operations.

METALLURGICAL ACID PLANTS

EPA is proposing that the metallurgical acid plants subcategory be expanded to include metallurgical acid plants at primary lead and primary zinc smelters as well as those at primary copper smelters. These operations, which were previously regulated under their respective primary metal subcategories, would now be subject to limitations for acid plants. This reorganization was based on the following reasons (additional detail may be found in Section IV):

1. Process similarity - The purpose of acid plants is to remove sulfur dioxide from smelter emissions and produce sulfuric acid as a marketable by-product regardless of the associated metal processing. Consequently, the processing methods of lead and zinc acid plants are similar to those used in copper acid plants.

2. Waste stream similarity - The process similarities lead to generation of the same waste streams, i.e., acid plant blowdown.

3. Similar waste stream characteristics - The normalized (based on 100 percent acid produced) wastewater flows generated by acid plants of all three metal types are quite similar. Further, the pollutant matrices, while varying in the concentrations of some pollutant metals, exhibited general similarities between the three types. More importantly, the ranges of concentrations found were not broad enough to warrant distinctive treatment techniques or suggest different performances achievable with BPT.

MODIFIED APPROACH TO STORMWATER

Stormwater, as in all effluent limitations guidelines, is only considered process wastewater when commingled with actual process wastewater. If commingling occurs, the stormwater, which usually does not contain significant pollutant loadings, is contaminated with the pollutants contained in the process wastewater, and as such should be subject to treatment. No allowance, however, is given for this additional flow, since stormwater is or can be segregated from the process wastewater. Should a sufficient number of plants demonstrate that segregation of stormwater would result in excessive costs, is not technically feasible, or demonstrate that contamination of stormwater with process pollutants is an unavoidable result of manufacturing processes, the Agency will consider modification of the proposed regulation as appropriate.

Existing BPT effluent limitations for the nonferrous metals subcategories primary copper smelting, secondary copper, and primary lead have promulgated stormwater exemptions. Facilities in these three subcategories are subject to a zero discharge requirement according to promulgated BPT effluent limitations; however, facilities meeting certain design capacity requirements could discharge, regardless of effluent quality, a volume of water falling within the impoundment in excess of the 10-year, 24-hour storm, when a storm of at least that magnitude occurred. Further, facilities in the secondary copper and primary lead subcategories can discharge once per month, subject to concentration-based effluent limitations, a volume of water equal to the difference between precipitation and evaporation falling on the impoundment in that month.

The Agency began to revise some of these impoundment-based regulations in 1980 for primary copper smelting and electrolytic refining BPT, this rulemaking session is proposing to revise others. The revised regulations are based on mechanical end-of-pipe treatment using hardware (lime precipitation and sedimentation technology using clarifiers). By eliminating impoundments, the need for a net precipitation allowance and (subject to an exception discussed below) stormwater discharge is eliminated. Table IX-1 summarizes the current stormwater precipitation allowances.

The Agency is reluctant to issue limitations based on impoundments for a number of reasons:

1. Discharge from impoundments can be as a "slug," allowing potentially heavy and damaging pollutant loadings to be discharged all at once;
2. Impoundments allow dilution of heavily contaminated process wastewaters with relatively cleaner process streams;
3. Net precipitation limitations are hard to calculate because of periodic shifts between net precipitation and net evaporation;
4. Impoundments pose a risk of groundwater contamination; and
5. Impoundment-based regulations effectively require the Agency to specify impoundment design.

(See generally 45 FR at 44926 (July 2, 1980), revising impoundment-based regulations in the primary copper smelting and electrolytic refining subcategories.) In addition, plants within these subcategories, have in many cases, already installed hardware-based lime precipitation and sedimentation technology, so that these technologies are now BPT or BAT for these subcategories.

In light of these considerations, an allowance for net precipitation is not included for BPT for the primary lead subcategory because the effluent limitations for BPT are not based on settling and evaporation impoundments. EPA is not proposing any modifications to promulgated BPT effluent limitations for the primary copper smelting and secondary copper subcategories. Table IX-2 summarizes the proposed changes to the catastrophic stormwater and precipitation allowances.

It is recognized that this approach to catastrophic rainfalls varies from the approach used for the ore mining and dressing category (47 FR 54603). In that regulation EPA required only that the impoundments be designed and operated so as to contain a 10-year, 24-hour storm, while this proposed regulation requires that no discharge from the impoundment may occur except when a 10-year, 24-hour storm occurs. This difference is justified by the fact that the nonferrous metals manufacturing allowance applies only to water falling on the surface of the impoundment while the ore mining allowance applies to stormwater drainage from various processing locations at the ore mine and mill. The relative surface area of a nonferrous manufacturing impoundment is a small fraction of the area drained at an ore mine and mill. Therefore, the quantity of stormwater that must be contained at a nonferrous plant impoundment is much smaller, making containment of the stormwater under the provisions of this proposed regulation achievable. The Agency believes that decisions regarding stormwater are site-specific and are best handled based on the judgment of individual permit writers.

BPT OPTION SELECTION

The treatment option selected for the technology basis of BPT throughout the category is Option A (lime precipitation and sedimentation, with ammonia steam stripping where appropriate). Lime precipitation, sedimentation, and ammonia steam stripping are widely demonstrated at plants with the best treatment practices in the nonferrous metals manufacturing category. Lime precipitation and sedimentation for dissolved toxic metals removal is demonstrated at 61 discharging facilities within the nonferrous metals manufacturing point source category. Ammonia steam stripping is demonstrated at three facilities and unspecified ammonia removal is demonstrated at five facilities. To illustrate the frequency of various treatment techniques, Table IX-3 summarizes the current treatment technology in-place for plants in each subcategory. As can be seen, the preponderance of technology is lime precipitation and sedimentation equipment. Multimedia filtration (Option C) as an add-on polishing step to the precipitation and sedimentation system was not selected at BPT since it was less widely demonstrated.

Effluent BPT limitations have not been promulgated for the following four subcategories:

1. Primary tungsten,
2. Primary columbium-tantalum,
3. Secondary silver, and
4. Secondary lead.

In the discussions that follow, a brief description of the option selected for each of these four subcategories will be presented.

A discussion of primary lead BPT option selection will also be presented since limitations for this subcategory are being modified. The mass limitations developed for these subcategories are presented in Section II of this document and the corresponding supplements. Table IX-4 presents the pollutants selected for limitation in each of these subcategories.

PRIMARY LEAD

The technology basis for the BPT limitations is lime precipitation and sedimentation technology to remove metals and solids from combined wastewaters and to control pH. This technology is demonstrated at three primary lead smelters and is estimated to remove 1,350 kg/yr of toxic pollutants and 84,000 kg/yr of conventional pollutants over estimated raw discharges. With the only discharger in this subcategory utilizing lime precipitation, sedimentation, and filtration, no costs are anticipated for the primary lead subcategory to meet the proposed BPT effluent limitations.

More stringent technology options were not selected for BPT, since they require in-process changes or end-of-pipe technologies not widely practiced in the primary lead subcategory. These technologies are more appropriately considered under BAT.

PRIMARY TUNGSTEN

The technology basis for the BPT limitations is lime precipitation and sedimentation technology to remove metals and solids from combined wastewaters and to control pH, and ammonia steam stripping to remove ammonia. These technologies are already in-place at both of the direct dischargers for this subcategory.

Implementation of the proposed BPT limitations will remove from raw wastewaters an estimated 3,560 kg of toxic metals, 741,470 kg of ammonia, and 2,658,600 kg of TSS. No capital or annual costs are projected for achieving proposed BPT because the technology is in-place at both discharging facilities.

More stringent technology options were not selected for BPT since they require in-process changes or end-of-pipe technologies not widely practiced in the subcategory, and, therefore, are more appropriately considered under BAT.

PRIMARY COLUMBIUM-TANTALUM

EPA is proposing BPT effluent mass limitations based on lime precipitation and sedimentation to control toxic metals, TSS, pH and fluoride, and ammonia steam stripping. These technologies are currently in-place at both of the direct dischargers in the primary columbium-tantalum subcategory.

Application of BPT technology will result in the removal of 145,000 kg of toxic pollutants, 1.5 million kg of conventional pollutants, and 1.3 million kg of nonconventional pollutants per year from current raw wastewaters. There is no cost associated with compliance with the proposed BPT mass limitations because the technology is already in-place at both of the direct discharging plants in the primary columbium-tantalum subcategory.

More stringent technology options were not selected since they require in-process changes or end-of-pipe technologies which are not widely practiced by the industry and, therefore, are more appropriately considered under BAT.

SECONDARY SILVER

The proposed BPT effluent mass limitations are based on lime precipitation and sedimentation to remove toxic metals, pH and TSS. Ammonia steam stripping is applied as pretreatment or removal of ammonia. Ammonia steam stripping is currently in place at two of the five direct dischargers in the secondary silver subcategory.

The proposed BPT will result in the removal of 27,000 kg of toxic pollutants and 578,350 kg of ammonia per year from raw discharge levels. The estimated capital investment cost of BPT is $0.124 million and the estimated annual cost is $0.263 million. These costs represent wastewater treatment equipment not currently in place. More stringent options were not selected for BPT because they involve in-process changes or end-of-pipe treatment technologies which are not widely practiced by the industry and, therefore, are more appropriately considered under BAT.

SECONDARY LEAD

The proposed BPT effluent mass limitations for the secondary lead subcategory are based on lime precipitation and sedimentation to control toxic metals, pH, and TSS. This technology is currently in-place at 23 discharging facilities in the secondary lead subcategory. In addition, dry kettle air pollution control is required, which eliminates the discharge of ammonia.

The proposed BPT will result in the removal of 14,400 kg of toxic pollutants and 5.4 million kg of conventional pollutants per year from raw discharge levels. The estimated capital investment cost of BPT is $0.470 million and the estimated annual cost is $0.228 million. These costs represent wastewater treatment equipment not currently in-place. More stringent options were not selected for BPT because they involve in-process changes or end-of-pipe treatment technologies which are not widely practiced by the industry and, therefore, are more appropriately considered under BAT.

EXAMPLES OF BUILDING BLOCK APPROACH IN DEVELOPING PERMITS

A plant is to receive a discharge allowance for a particular building block only if it is actually operating that particular process. In this way, the building block approach recognizes and accommodates the fact that not all plants use identical steps in manufacturing a given metal. The plant need not be discharging wastewater from the process to receive the allowance, however. Thus, if the regulation contains a discharge allowance for wet scrubber effluent and a particular plant has dry scrubbers, it cannot include a discharge allowance for wet scrubbers as part of its aggregate limitation. On the other hand, if it has wet scrubbers and discharges less than the allowable limit or does not discharge from the scrubbers, it would receive the full regulatory allowance in developing the permit.

There are several facilities within this category that have integrated manufacturing operations; that is, they combine wastewater from smelting and refining operations, which are part of this point source category, with wastewater from other manufacturing operations which are not a part of this category, and treat the combined stream prior to discharge.

The building block approach is only to be used when the individual discharger combines wastewater from various processes and co-treats the wastewater before discharge through a single discharge pipe. The building block approach allows the determination of appropriate effluent limitations for the discharge point by combining appropriate limitations based upon the various processes that contribute wastewater to the discharge point.

In establishing limitations for integrated facilities for which a portion of the plant is covered by concentration-based limitations, the permit writer can determine the appropriate mass limitations for the entire facility or point source. The portion of the wastewater covered by this category receives mass limitations according to the building block methodology described above. The permit writer must then determine an appropriate flow for the portion of the facility subject to concentration-based limitations and multiply it by the concentration limitations to yield mass limitations. The mass limitations applicable to the discharge are obtained by summing these two sets of mass limitations.

As an example, consider a facility which combines both secondary lead smelting and battery manufacturing wastewater and treats this water in a waste treatment system prior to discharge. The permit writer must first identify the manufacturing operations using process water in the facility. The facility in this example utilizes and discharges wastewater from the processes shown below. By multiplying the production for each of these operations by the limitations or standards in 40 CFR 421 for secondary lead production and 40 CFR 461 for battery manufacturing, the permit writer can obtain the allowable mass discharge.

Process	Production
Battery Cracking	8,400 kkg/yr
Kettle Wet Air Pollution Control	18,300 kkg/yr
Casting Contact Cooling	18,300 kkg/yr
Lead Oxide Purchased	2,600,000 kg/yr
Paste Preparation and Application	5,200,000 kg/yr
Curing Stacked	5,200,000 kg/yr
Formation - Closed, Single	4,160,000 kg/yr
Formation - Open, Dehydrated	1,040,000 kg/yr
Battery Wash - With Detergent	5,200,000 kg/yr

Using the maximum for any one day limitation based on the best practicable control technology (BPT) for the pollutant lead is 3.75 kg/yr as calculated below:

Battery Cracking

(141.0 mg/kkg) (8,400 kkg/yr) (10^{-6} kg/mg) = 1.18

Kettle Wet Air Pollution Control

(0 mg/kkg) (18,300 kkg/yr) (10^{-6} kg/mg) = 0

Casting Contact Cooling

33.18 mg/kkg) (18,300 kkg/yr) (10^{-6} kg/mg) = 0.61

Secondary Lead Production Subtotal = 1.79 kg/yr

Paste Preparation and Application

(0 mg/kg) (5,200,000 kg/yr) (10^{-6} kg/mg) = 0

Curing Stacked

(0 mg/kg) (5,200,000 kg/yr) (10^{-6} kg/mg) = 0

Formation - Closed, Single

(0 mg/kg) (4,160,000 kg/yr) (10^{-6} kg/mg) = 1

Formation - Open, Dehydrated

(1.35 mg/kg) (1,040,000 kg/yr) (10^{-6} kg/mg) = 1.404

Battery Wash - With Detergent

(0.108 mg/kg) (5,200,000 kg/yr) (10^{-6} kg/mg) = 0.56

Battery Manufacturing Subtotal = 1.96 kg/yr

Facility Total = 3.75 kg/yr

In establishing limitations for integrated facilities for which a portion of the plant is covered by concentration-based limitations, the permit writer can determine the appropriate mass limitations for the entire facility or point source as follows. The portion of the wastewater covered by this category receives mass limitations according to the building block methodology described above. The permit writer must then determine an appropriate flow for the portion of the facility subject to concentration-based limitations and multiply it by the concentration limitations to yield mass limitations. The mass limitations applicable to the discharge are obtained by summing these two sets of mass limitations. If, instead, the waste stream is not covered by any limitations, the permit writer must then also determine the appropriate concentration as well.

As an example, we will use a facility which combines process wastewater from a mill using froth flotation to concentrate lead ore with blast furnace slag granulation wastewater from a primary lead smelter. The portion of the limitations attributable to the casting water is calculated by multiplying the limitations in Subpart E of 40 CFR 421 in today's notice by the casting production. The permit writer must then determine the appropriate flow for the discharge from the mill and multiply it by the concentrations set forth in Subpart J of 40 CFR 440 at 47 FR 54618. If the casting production is 175,000 kkg per year and the flow from the froth flotation mill is 2,000,000 l/yr, the maximum for any one day limitation based on the best available technology economically achievable (BAT) for the pollutant lead is 99.1 kg/yr as calculated below:

Blast Furnace Slag Granulation

(559.5 mg/kkg) (175,000 kkg/yr) (10^{-6} kg/mg) = 97.9 kg/yr

Froth Flotation Mill Wastewater

(0.6 mg/l) (2,000,000 l/yr) (10^{-6} kg/mg) = 1.2 kg/yr

Total = 99.1 kg/yr

Table IX-1

STORMWATER/PRECIPITATION ALLOWANCES

Subcategory	Existing Regulations			
	BPT		BAT	
	Catastrophic Storm	Net Precipitation	Catastrophic Storm	Net Precipitation
Primary Copper Smelting	Yes	No	Yes	Yes
Primary Copper Electrolytic Refining	No	No	Yes	Yes
Secondary Copper	Yes	Yes	Yes	Yes
Primary Lead	Yes	Yes	Yes	Yes

Subcategory	Proposed Regulations					
	BPT		BAT		NSPS	
	Catastrophic Storm	Net Precipitation	Catastrophic Storm	Net Precipitation	Catastrophic Storm	Net Precip-tation
Primary Copper Smelting	--	--	Yes	No	No	No
Primary Copper Electrolytic Refining	--	--	No	No	No	No
Secondary Copper	--	--	Yes	No	No	No
Primary Lead	No	No	No	No	No	No

Table IX-1 (Continued)

STORMWATER/PRECIPITATION ALLOWANCES

	Proposed Regulations			
	PSES		PSNS	
Subcategory	Catastrophic Storm	Net Precipitation	Catastrophic Storm	Net Precipitation
Primary Copper Smelting	--*	--	No	No
Primary Copper Electrolytic Refining	--*	--	No	No
Secondary Copper	No	No	No	No
Primary Lead	--*	--	No	No

Yes = Regulation contains this allowance.
No = Regulation does not contain this allowance.

*No existing indirect dischargers.

Table IX-2

MODIFICATION TO BPT PRECIPITATION EXEMPTION

	Existing BPT Regulation		Proposed BPT Regulation	
Subcategory	Catastrophic Storm	Net Precipitation	Catastrophic Storm	Net Precipitation
Secondary Copper	Yes	Yes	Yes	No
Primary Lead	Yes	Yes	No	No

Yes = Regulation contains this allowance.
No = Regulation does not contain this allowance.

Table IX-3

SUMMARY OF CURRENT TREATMENT PRACTICES

SUBCATEGORY	Lime and Settle[1]	Lime, Settle and Filter	Oil Skimming	Ammonia Stripping			Discharge Status			
				Air	Steam	Unspecified	Direct	Indirect	Zero	Total
Primary Aluminum	13 (0)[2]	1 (0)					27		4	31
Secondary Aluminum	4 (4)				1		8	13	34	55
Primary Copper Smelters	4 (4)						2		18	20
Primary Copper Refiners	2 (1)	1 (0)	1 (1)				4		11	15
Secondary Copper	4 (3)	1 (1)					5	6	20	31
Primary Lead	2 (1)	1 (0)					1		6	7
Secondary Lead	23 (6)	7 (0)			1		7	16	46	69
Primary Zinc	7 (1)	3 (1)					5		2	7
Secondary Silver	7 (0)	3 (0)					4	17	23	44
Primary Columbium/Tantalum	4 (0)	1 (0)			1 (0)	1 (0)	3	2		5
Primary Tungsten	3 (0)	3 (0)				4 (2)	2	3	3	8
Metallurgical Acid Plants	8 (0)	3 (0)					8	1	13	22

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[1] These number on this column include plants tallied in the lime, settle and filter column.

[2] Numbers in parentheses indicate zero dischargers with treatment.

Table IX-4

REGULATED POLLUTANT PARAMETERS

Subcategory	Pollutant Parameters
Primary Lead	122. lead 128. zinc TSS pH
Primary Tungsten	122. lead 125. selenium 128. zinc ammonia (N) TSS pH
Primary Columbium-Tantalum	122. lead 128. zinc ammonia (N) fluoride TSS pH
Secondary Silver	120. copper 128. zinc ammonia (N) TSS pH
Secondary Lead	114. antimony 115. arsenic 122. lead 128. zinc TSS pH

SECTION X

EFFLUENT QUALITY ATTAINABLE THROUGH APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

This section sets forth the effluent limitations attainable through the application of best available technology economically achievable (BAT). It also serves to summarize changes from previous rulemakings in the nonferrous metals manufacturing category, and presents the development and use of the mass-based effluent limitations.

A number of factors guide the BAT analysis including the age of equipment and facilities involved, the process employed, process changes, nonwater quality environmental impacts (including energy requirements), and the costs of application of such technology. BAT technology represents the best available technology economically achievable at plants of various ages, sizes, processes, or other characteristics. In those categories whose existing performance is uniformly inadequate EPA may transfer technology from a different subcategory or category. BAT may include process changes or internal controls, even when these are not common industry practice. This level of technology also considers those plant processes and control and treatment technologies which, at pilot plant and other levels, have demonstrated both technological performance and economic viability at a level sufficient to justify investigation.

The required assessment of BAT "considers" costs, but does not require a balancing of costs against effluent reduction benefits (see Weyerhaeuser v. Costle, 11 ERC 2149 (D.C. Cir. 1978)). In developing the proposed BAT, however, EPA has given substantial weight to the economic achievability of the technology. The Agency has considered the volume and nature of discharges expected after application of BAT, the general environmental effects of the pollutants, and the costs and economic impacts of the required pollution control levels.

The BAT effluent limitations are organized by subcategory for individual sources of wastewater. The limitations were developed based on the attainable effluent concentrations and production normalized flows that have been presented in this document. The analysis has resulted in a number of modifications to the existing BAT regulatory structure. Implementation of the proposed BAT effluent limitations is expected to remove 175,500 kg/yr of toxic pollutants and 2,582,000 kg/yr of conventional and nonconventional pollutants above BPT discharge estimates. The estimated capital cost of BAT is $48.46 million (1978 dollars), and the estimated annual cost is $27.55 million (1978 dollars).

TECHNICAL APPROACH TO BAT

In the past, the technical approach for the nonferrous metals manufacturing category considered each plant as a single wastewater source, without specific regard to the different unit processes that are used in plants within the same subcategory. For this rulemaking, end-of-pipe treatment technologies and in-process controls were examined in the selection of the best available technology. After examining in-process controls, it becomes apparent that it was best to establish effluent limitations and standards recognizing specific waste streams associated with specific manufacturing operations. The approach adopted for this proposal considers the individual wastewater sources within a plant, resulting in more effective pollution abatement by tailoring the regulation to reflect these various wastewater sources. This approach, known as the building block approach, was presented in Section IX.

INDUSTRY COST AND POLLUTANT REDUCTION BENEFITS OF THE VARIOUS TREATMENT OPTIONS

Under these guidelines, six treatment options were evaluated in selection of BAT for the category. Because of the diverse processes and raw materials used in the nonferrous category, the pollutant parameters found in various waste streams are not uniform. This required the identification of significant pollutants in the various waste streams so that appropriate treatment technologies could be selected for further evaluation. The options considered applicable to the nonferrous metals manufacturing subcategories are presented in Table X-1. A thorough discussion of the treatment technologies considered applicable to wastewaters from the nonferrous metals manufacturing category is presented in Section VII of this document. In Section VII, the attainable effluent concentrations of each technology are presented along with their uniform applicability to all subcategories. Mass limitations developed from these options may vary, however, because of the impact of different production normalized wastewater discharge flows.

In summary, the treatment technologies considered for nonferrous metals manufacturing are:

Option A is based on:

Lime and settle (chemical precipitation of metals followed by sedimentation), and, where required,

Ammonia steam stripping, and

Oil skimming.

(This option is equivalent to the technology on which BPT is based.)

Option B is based on:

> Option A (lime and settle) plus cyanide precipitation, where required, and process wastewater flow reduction by the following methods:
>
> - Contact cooling water recycle through cooling towers.
> - Holding tanks for all other process wastewater subject to recycle.

Option C is based on:

> Option B (lime and settle preceded by flow reduction), plus multimedia filtration.

Option D_1 is based on:

> Option C (lime precipitation, sedimentation, in-process flow reduction, and multimedia filtration); plus activated alumina treatment, where required.

Option D_2 is based on:

> Option C (lime precipitation, sedimentation, in-process flow reduction, and multimedia filtration); plus activated carbon adsorption preliminary treatment, where required.

Option E is based on:

> Option C (lime precipitation, sedimentation, in-process flow reduction, and multimedia filtration); plus activated carbon adsorption at the end of the Option C treatment scheme.

Option F is based on:

> Option C (lime precipitation, sedimentation, in-process flow reduction, and multimedia filtration); plus reverse osmosis treatment to attain complete recycle of all process wastewater.

As a means of evaluating the economic achievability of each of these treatment options, the Agency developed estimates of the compliance costs and pollutant reduction benefits. An estimate of capital and annual costs for the applicable BAT options was prepared for each subcategory as an aid in choosing the best BAT option. The cost estimates are presented in Section X of each of the subcategory supplements. All costs are based on fourth quarter 1978 dollars.

The cost methodology has been described in detail in Section VIII. For most treatment technologies, standard cost literature sources were used for module capital and annual costs. Data from several sources were combined to yield average or typical costs as a function of flow or other characteristic design parameters. In a small number of modules, the technical literature was reviewed to identify the key design criteria, which were then used as a basis for vendor contacts. The resulting costs for individual pieces of equipment were combined to yield module costs. In either case, the cost data were coupled with flow data from each plant to establish system costs for each facility.

Pollutant reduction benefit estimates were calculated for each option for each subcategory. The estimated pollutant removal that the treatment technologies can achieve is presented in Section X of each of the subcategory supplements.

The first step in the calculation of the benefit estimates is the calculation of production normalized raw waste values (mg/kkg) for each pollutant in each waste stream. The raw waste values were calculated using one of three methods. When analytical concentration data (mg/l) and sampled production normalized flow values (l/kkg) were available for a given waste stream, individual raw waste values for each sample were calculated and averaged. This method allows for the retention of any relationship between concentration, flow and production. When sampled production normalized flows were not available for a given waste stream, an average concentration was calculated for each pollutant, and the average raw waste normalized flow taken from the dcp information for that waste stream was used to calculate the raw waste. When analytical values were not available for a given waste stream, the raw waste values for a stream of similar water quality was used.

The total flow (l/yr) for each option for each subcategory was calculated by summing individual flow values for each waste stream in the subcategory for each option. The individual flow values were calculated by multiplying the total production associated with each waste stream in each subcategory (kkg/yr) by the appropriate production normalized flow (l/kkg) for each waste stream for each option.

The raw waste mass values (kg/yr) for each pollutant in each subcategory were calculated by summing individual raw waste masses for each waste stream in the subcategory. The individual raw waste mass values were calculated by multiplying the total production associated with each waste stream in each subcategory (kkg/yr) by the raw waste value (mg/kkg) for each pollutant in each waste stream.

The mass discharged (kg/yr) for each polultant for each option for each subcategory was calculated by multiplying the total flow (l/yr) for those waste streams which enter the central treatment system, by the treatment effectiveness concentration (mg/l) (Table VII-22) for each pollutant for the appropriate option.

The total mass removed (kg/yr) for each pollutant for each option for each subcategory was calculated by subtracting the total mass discharged (kg/yr) from the total raw mass (kg/yr).

Total treatment performance values for each subcategory were calculated by using the total production (kkg/yr) of all plants in the subcategory for each waste stream. Treatment performance values for direct dischargers in each subcategory were calculated by using the total production (kkg/yr) of all direct dischargers in the subcategory for each waste stream.

MODIFICATION OF EXISTING BAT EFFLUENT LIMITATIONS

Modifications are proposed to all existing promulgated BAT effluent limitations in the nonferrous metals manufacturing category. In general, the existing BAT effluent limitations are being modified to incorporate the building block approach. A detailed discussion regarding the development of mass limitations from this approach is presented in Section IX. Other modifications to the primary lead subcategory and secondary aluminum subcategory are a result of new information supplied to the Agency.

To reflect the changes in stormwater allowances promulgated for BPT in the primary copper smelting and secondary copper subcategories, the Agency is proposing modifications to the stormwater allowances promulgated under BAT. The proposed changes allow a discharge resulting from a catastrophic rainstorm, but they eliminate the monthly net precipitation discharge allowance. The building block approach is not developed for these two subcategories since they are required to maintain zero discharge of all process wastewater pollutants.

The technology basis for BAT is also being modified. Lime precipitation, sedimentation and filtration is being proposed. The Agency believes this represents the best available technology economically achievable. The proposed limitations are based on achievable concentrations from two porcelain enameling plants and one nonferrous metals plant and variability factors from the combined data base.

Primary Aluminum

The existing BAT effluent limitations were developed by considering each plant as a single wastewater source and allocating one discharge rate from which the effluent limitations were calculated. The technology basis from which these effluent limitations were developed are lime and settle performance values. The proposed BAT effluent limitations are developed for individual wastewater sources identified within the primary aluminum subcategory, and effluent concentrations attainable with lime precipitation, sedimentation, filtration, cyanide precipitation, and activated carbon adsorption. This technology is discussed in greater detail in the BAT option selection of this section.

Secondary Aluminum

The currently promulgated BAT for this subcategory prohibits the discharge of process wastewater. However, new information supports the need for discharge of wastewater from chlorine demagging, an operation considered and included in the promulgated zero discharge regulation. Three dry processes existed at the time of promulgation; the Durham process; the Alcoa process; and the Teller process. The Agency believed that each of these processes were sufficiently well demonstrated to be installed and become operational by 1984; the compliance date for BAT. Consequently, there was no justification for a discharge allowance associated with this waste stream.

New information shows that the technologies are not sufficiently demonstrated nor are they applicable to plants on a nationwide basis. For this reason, the promulgated BAT is being modified; the proposed BAT is based on the use of wet scrubbing on chlorine demagging operations.

Information has become available to the Agency that supports the need for discharge of wastewater from direct chill casting, an operation not considered nor included in the promulgated BAT regulation. Direct chill casting is a relatively new process and companies have been installing this technology into their plants over the past five years. The process has been considered as a part of the rulemaking and effluent limitations that allow a discharge are being proposed.

Primary Electrolytic Copper Refining

The existing BAT effluent limitations were developed by considering each plant as a single wastewater source and allocating one discharge rate from which the effluent limitations were calculated. The technology basis was lime precipitation and sedimentation performance values. The proposed BAT effluent limitations are developed for individual wastewater sources identified within the primary electrolytic copper refining subcategory, and effluent concentrations attainable with lime precipitation, sedimentation, in-process flow reduction, and multimedia filtration. This technology is discussed in greater detail in the BAT option selection of this section.

Primary Lead

With the exception of stormwater exemptions, the existing BAT effluent limitations require zero discharge of all process wastewater pollutants. Information supplied to the Agency shows that slag removed from the smelting furnace may contain recoverable concentrations of lead. For the smelter slag to be recycled back into the production process, it must be granulated so that it is compatible with concentrated ore. The Agency has determined that this waste stream requires a discharge to control the buildup of suspended solids.

Primary Zinc

The existing BAT effluent limitations were developed from one wastewater discharge rate and lime and settle performance values. The proposed BAT effluent limitations are developed for individual wastewater sources identified within the primary zinc subcategory, and effluent concentrations attainable with lime precipitation, sedimentation, in-process flow reduction, and multimedia filtration. This technology is discussed in greater detail in the BAT option selection of this section.

Metallurgical Acid Plants

As discussed in Section IX, the metallurgical acid plants subcategory is being modified to include acid plants associated with primary zinc and lead smelters as well as primary copper smelters. This is based on the similarity between discharge rates and effluent characterisitcs of wastewaters from primary lead, zinc, and copper smelting acid plants.

MODIFIED APPROACH TO STORMWATER

For the same reasons discussed in detail in Section IX, no allowance will be given for stormwater under BAT. Stormwater is or can be segregated from the process wastewater. Furthermore, stormwater is site-specific and is best addressed on a case-by-case basis by the permit writer. Should a sufficient number of plants demonstrate that segregation of stormwater would result in excessive costs, is not technically feasible, or demonstrate that contamination of stormwater with process pollutants is an unavoidable result of manufacturing processes, the Agency will consider modification of the proposed regulation as appropriate.

The BAT regulations on catastrophic and net precipitation exemptions are modified for several subcategories. These changes are presented in Table X-2. The reasons for modifying the BAT relief provisions for primary copper smelting, primary copper electrolytic refining, secondary copper and primary lead are as follows:

1. The technology basis for BAT has been changed from wastewater impoundments to equipment such as holding tanks, cooling towers, and clarifiers. This type of equipment is not influenced to the same degree as cooling impoundments. As a result, storm relief is not necessary to treat process wastewater (with the exception noted in (2) below).

2. For primary copper smelting and secondary copper, impoundments to treat cooling water are used at many facilities as an alternative to cooling towers. EPA has thus provided that stormwater may be discharged from these impoundments when a 25-year, 24-hour storm or larger has been experienced by the facility. The volume of water that may be discharged is only that which falls directly on the impoundment surface. Further, since the size required for cooling water impoundments is substantially smaller than impoundments that treat other process wastewaters, no net precipitation relief is necessary. The amount of freeboard available in the proper design and operation of these cooling water ponds is sufficient for most facilities to accommodate the fluctuations in volume resulting from the precipitation cycle without having to discharge.

BAT OPTION SELECTION

The option generally selected throughout the category is Option C or lime precipitation, sedimentation, in-process flow reduction, multimedia filtration, and ammonia steam stripping, where applicable. The Agency has selected BPT plus in-process wastewater flow reduction and the use of filtration as an effluent polishing step as BAT for all of the subcategories except primary aluminum, where additional treatment is proposed for the control of toxic organics and cyanide.

This combination of treatment technologies has been selected because they are technically feasible and are demonstrated within the nonferrous metals manufacturing category. Implementation of this treatment scheme would result in the removal of an estimated 175,500 kg/yr of toxic pollutants and 2,582,000 kg/yr of conventional pollutants above BPT discharge estimates. Although the Agency is not required to balance the costs against effluent reduction benefits (see Weyerhaeuser v. Costle, supra), the Agency has given substantial weight to the reasonableness of cost. The Agency's current economic analysis shows that this combination of treatment technologies is economically achievable. No closures of indirect dischargers are expected as a result of compliance with recommended BAT technologies. Price increases are not expected to exceed 0.5 percent with production decreases of less than 0.5 percent.

The general approach taken by the Agency for BAT regulation of this category is presented below. The actual proposed limitations may be found in Section II of this document. The BAT option selected for each subcategory is presented below.

Primary Aluminum

The BAT option selected is flow reduction, lime precipitation, sedimentation, and filtration for control of toxic metals and fluoride; activated carbon preliminary treatment for toxic organics removal; and cyanide precipitation pretreatment.

This combination of treatment technologies was selected because it provides additional pollutant removal achievable by the primary aluminum subcategory and it is economically achievable. Lime precipitation and sedimentation are widely practiced at primary aluminum plants, and as indicated in the previous section, form the basis for the BPT limitations. Filtration serves as an important polishing step in BAT. For this subcategory, it results in the removal of 1,214,000 kg/yr of toxic pollutants and 1,390,000 kg/yr of nonconventional pollutants over the estimated BPT discharge. Further, lime precipitation and sedimentation are demonstrated at 13 primary aluminum smelters, while filtration is demonstrated at 23 plants in the nonferrous metals manufacturing category including one plant in the primary aluminum subcategory. The estimated capital investment cost of BAT is $34.85 million and the annualized cost is $18.71 million.

The activated carbon pretreatment step is directed at better control of discharges from wet air emission scrubbing associated with anode paste plants, anode bake plants, potlines and potrooms; as well as from cathode reprocessing operations. As an alternative method of controlling these discharges, a plant could install a dry alumina air scrubber or institute 100 percent recycle of wet scrubbing discharges. Although the activated carbon adsorption is not demonstrated in this subcategory, the Agency has compiled data from two iron and steel plants with activated carbon. These data demonstrate its applicability to and performance for removing the polynuclear aromatic hydrocarbons produced by primary aluminum plants.

Cyanide precipitation pretreatment is directed at control of free and complexed cyanides in waste streams within the primary aluminum subcategory that result from use of coke and pitch in the electrolytic reduction process. These waste streams collectively discharge approximately 121,000 kg/yr of cyanide. While cyanide precipitation has not been demonstrated in the primary aluminum subcategory, it is used at six coil coating plants. The Agency believes this technology is transferable to the primary aluminum subcategory because raw wastewater cyanide concentrations are of the same order of magnitude in both categories prior to dilution with waste streams without cyanide. Further, no pollutants were identified in primary aluminum wastewater that would interfere with the operation or performance of this technology.

Flow reduction is an important element of BAT because it results in reduced dilution of pollutants and smaller hydraulic flows, which in turn lead to more efficient treatment, smaller treatment systems, and an associated reduction in the net cost of treatment. Wastewater flow reduction is based on increased recycle of scrubber liquor from degassing, potline, potroom, and anode bake scrubbers, in addition to casting contact cooling water.

More complex technologies were also considered as BAT, including end-of-pipe activated alumina for the control of fluoride and reverse osmosis. These two technologies were rejected because they are not demonstrated in the nonferrous metals manufacturing category nor are they clearly transferable.

Secondary Aluminum

EPA is proposing BAT effluent mass limitations for the secondary aluminum subcategory based on lime precipitation, sedimentation, filtration and ammonia steam stripping. Ammonia steam stripping is selected by the Agency over air stripping because air stripping reduces ammonia concentrations by simply transferring pollutants from one media (water) to another (air). Steam stripping reduces ammonia concentrations by stripping the ammonia from wastewater with steam. The ammonia is concentrated in the steam phase and may be condensed, collected, and sold as a by-product or disposed off-site. Ammonia steam stripping is demonstrated by three facilities in the nonferrous metals manufacturing category and one plant in the secondary aluminum subcategory. Filtration is not demonstrated in the secondary aluminum subcategory, however, it is demonstrated in the nonferrous metals manufacturing category.

Application of the proposed BAT will result in the removal of 173 kg of toxic pollutants and 45.6 kg of nonconventional pollutants above the estimated BPT removal. The estimated capital investment cost of the proposed BAT is $1.60 million and the estimated annualized cost is $1.35 million.

Reverse osmosis was also examined for BAT. This technology, however, is not demonstrated in the category, nor is it clearly transferable.

Primary Copper Electrolytic Refining

Due to adverse economic conditions that are not reflected by the Agency's current economic analysis, EPA is proposing alternative BAT effluent mass limitations for the primary copper electrolytic refining subcategory. After revision of the economic analysis and consideration of public comment, EPA will select a technology basis for the promulgated BAT. In the interim, the Agency is soliciting comment on two options in order to assure that commentors consider both options. Alternative A is based on the existing BPT of lime precipitation and sedimentation with additional reduction in pollutant discharge achieved through in-process wastewater flow reduction. Alternative B adds the use of filtration as an effluent polishing step. Wastewater flow reduction is based on increased recycle of spent electrolyte, anode rinse water and casting contact cooling water. None of the four direct discharging plants in the primary copper electrolytic refining subcategory currently practice filtration of wastewater.

Application of the proposed Alternative A BAT will result in the removal of 2,691 kg of toxic pollutants and 23,442 kg of nonconventional pollutants above the estimated BPT discharge. The estimated capital investment cost of the proposed BAT is $0.328 million and the estimated annualized cost is $0.239 million.

Application of the proposed Alternative B BAT will result in the removal of 2,864 kg of toxic pollutants and 25,935 kg of nonconventional pollutants above the estimated BPT discharge. The estimated capital investment cost of the proposed BAT is $0.487 million and the estimated annualized cost is $0.290 million.

Reverse osmosis was also considered for BAT. It was rejected, however, because it is not demonstrated in the category, nor is it clearly transferable.

Primary Lead

EPA is proposing BAT effluent mass limitations for the primary lead subcategory based on the existing BPT with additional reduction in pollutant discharge achieved through in-process wastewater flow reduction and the use of filtration as an effluent polishing step. Wastewater flow reduction is based on the complete recycle of process wastewater from zinc fuming wet air pollution control, dross reverberatory furnace granulation, and hard lead refining wet air pollution control. Wastewater generated from slag granulation is the only waste stream allocated a discharge allowance. Filtration is currently demonstrated by one facility in the primary lead subcategory.

Application of the proposed BAT will result in the removal of 173 kg of toxic pollutants and 4,985 kg of nonconventional pollutants above the estimated BPT discharge. The primary lead subcategory is not expected to incur any costs to implement the technology basis from which BAT is developed. Reverse osmosis was also considered for BAT; however, it is not demonstrated in the category, nor is it clearly transferable.

Primary Zinc

EPA is proposing BAT effluent mass limitations for the primary zinc subcategory based on BPT with additional reduction in pollutant discharge achieved through in-process wastewater flow reduction and the use of filtration as an effluent polishing step. (Wastewater flow reduction is based on increased recycle of casting scrubber water and casting contact cooling water.) Filtration is currently in place at two of the five direct discharging plants in the primary zinc subcategory.

Application of the proposed BAT effluent mass limitations will result in the removal of 5,390 kg of toxic pollutants above the estimated BPT discharge. The estimated capital investment cost of the proposed BAT is $2.56 million and the estimated annualized cost is $1.63 million. Activated alumina and reverse osmosis were also considered for BAT but were rejected. These technologies are not demonstrated in the category, nor are they clearly transferable.

Metallurgical Acid Plants

EPA is proposing BAT effluent mass limitations for metallurgical acid plants based on BPT with additional reduction in pollutant discharge achieved through in-process wastewater flow reduction and the use of filtration as an effluent polishing step. Wastewater flow reduction is based on increased recycle of acid plant scrubber liquor. Filtration is currently demonstrated at three of the eight direct discharging plants in the metallurgical acid plants subcategory.

Application of the proposed BAT mass limitations will result in the removal of 9,400 kg of toxic pollutants per year above the estimated BPT discharge. The estimated capital investment cost of BAT is $3.55 million and the annualized cost is $2.18 million.

The filtration option was selected instead of BPT plus flow reduction because it is demonstrated and results in removal of 1,114 kg/yr of toxic pollutants. Reverse osmosis was considered but it was rejected because it is not demonstrated in the category, nor is it clearly transferable.

Primary Tungsten

EPA is proposing BAT mass limitations for the primary tungsten subcategory based on BPT with additional reduction in pollutant discharge achieved through in-process wastewater flow reduction and the use of filtration as an effluent polishing step. Wastewater flow reduction is based on 90 percent recycle of scrubber liquors. Filtration is currently in place at three plants in the subcategory.

Application of the proposed BAT will remove an estimated 144 kg/yr of toxic pollutants, which is 127 kg/yr of toxic metals over the estimated BPT discharge. No additional ammonia is removed at BAT, nor are any toxic organics removed. The proposed BAT represents a 22 percent incremental toxics removal over BPT, and 89 percent total toxics removal from raw waste. Approximately half of these removals are attributable to flow reduction, the remainder to filtration. The estimated capital investment cost of BAT is $447,000, and the estimated annual cost is $193,000.

The filtration option was selected instead of BPT plus flow reduction because it is demonstrated and results in removal of 54 kg/yr of toxic metals. More stringent options were also considered but were rejected. Activated carbon adsorption was considered for the control of toxic organics. The Agency determined that the current discharge rate of toxic pollutants by the primary tungsten subcategory are not causing, nor are they likely to cause toxic effects in navigable waters. Reverse osmosis was rejected for BAT because it is not demonstrated in the category, nor is it clearly transferable.

Primary Columbium-Tantalum

EPA is proposing BAT mass limitations for the primary columbium-tantalum subcategory based on BPT with additional reduction in pollutant discharge achieved through in-process wastewater flow reduction and the use of filtration as an effluent polishing step. Wastewater flow reduction is based on increased recycle of scrubber liquors associated with three sources: concentrate digestion scrubber, solvent extraction scrubber, and metal salt drying scrubber. Filtration is currently in place at one of the two direct discharging plants in the primary columbium-tantalum subcategory.

Application of the proposed BAT will result in the removal of 285 kg/yr of toxic pollutants and 2,360 kg/yr of conventional pollutants over the estimated BPT discharge. The estimated capital investment cost of BAT is $797,000 and the estimated annual cost is $396,000.

The filtration option was selected instead of BPT plus flow reduction because it is demonstrated and results in removal of 129 kg/yr of toxic pollutants and 1,575 kg/yr of nonconventional pollutants. Activated carbon adsorption was considered for the control of toxic organics. The Agency determined that the current discharge rate of toxic pollutants by the primary columbium-tantalum subcategory are not causing, nor are they likely to cause toxic effects in navigable waters. Reverse osmosis was rejected for BAT because it is not demonstrated in the category, nor is it clearly transferable.

Secondary Silver

Due to adverse economic conditions that are not reflected by the Agency's current economic analysis, EPA is proposing alternative BAT mass limitations for the secondary silver subcategory in a manner similar to that explained for primary copper refining. Alternative A for secondary silver is based on BPT with additional reduction in pollutant discharge achieved through in-process wastewater flow reduction. Alternative B adds the use of filtration as an effluent polishing step. Wastewater flow reduction is based on increased recycle of leaching scrubber water, furnace scrubber water and casting contact cooling water. Filtration is currently in place at one of the five direct discharging plants in the secondary silver subcategory.

Application of the proposed Alternative A BAT will result in the removal of 13 kg/yr of toxic pollutants, 4 kg/yr of conventional pollutants, and 79 kg/yr of ammonia above the estimated BPT discharge. The estimated capital investment cost of the proposed Alternative A BAT is $184,000 and the annual cost is $278,000.

Application of the proposed Alternative B BAT will result in the removal of 92 kg/yr of toxic pollutants, 1,880 kg/yr of conventional pollutants, and 79 kg/yr of ammonia above the estimated BPT discharge. The estimated capital investment cost of the proposed Alternative B BAT is $206,000 and the annual cost is $345,000.

The filtration option was selected instead of BPT plus flow reduction because it is demonstrated and results in removal of 78 kg/yr of toxic pollutants. Activated carbon adsorption was considered for the control of toxic organics. The Agency determined that the current discharge rate of toxic pollutants by the secondary silver subcategory are not causing, nor are they likely to cause toxic effects in navigable waters. Reverse osmosis was rejected for BAT because it is not demonstrated in the category, nor is it clearly transferable.

Secondary Lead

Due to current adverse economic conditions that are not reflected in the Agency's current economic analysis, EPA is proposing alternative BAT effluent mass limitations for the secondary lead subcategory in a manner similar to the approach used for primary copper refining and secondary silver. Alternative A is based on BPT with additional reduction in pollutant discharge achieved through in-process wastewater flow reduction. Alternative B adds to Alternative A with the use of filtration as an effluent polishing step. Wastewater flow reduction is based on increased recycle of smelter scrubber water and casting contact cooling water, and reducing the amount of water used for battery cracking. Filtration is currently in place at two of the five direct discharging plants in the secondary lead subcategory.

Application of the proposed Alternative A BAT will result in the removal of 131.5 kg/yr of toxic pollutants and 918 kg/yr of conventional pollutants above the estimated BPT discharge. The estimated capital investment cost of BAT is $470,000, and the estimated annual cost is $228,000.

Application of the proposed Alternative B BAT will result in the removal of 250 kg/yr of toxic pollutants and 2,850 kg/yr of conventional pollutants above the estimated BPT discharge. The estimated capital investment cost of this alternative is $2.12 million, and the estimated annual cost is $1.36 million.

Reverse osmosis was considered for BAT, but it was rejected. Reverse osmosis is not demonstrated in the category, nor is it clearly transferable.

REGULATED POLLUTANT PARAMETERS

Presented in Section VI of this document is a list of the pollutant parameters at concentrations and frequencies above treatable concentrations that warrant further consideration. Although these pollutants were found at treatable concentrations, the Agency is not proposing to regulate each pollutant selected for further consideration. The high cost associated with analysis of toxic metal pollutants has prompted EPA to develop an alternative method for regulating and monitoring toxic pollutant discharges from the nonferrous metals manufacturing category. Rather than developing specific effluent mass limitations and standards for each of the toxic metals found in treatable concentrations in the raw wastewater from a given subcategory, the Agency is proposing effluent mass limitations only for those pollutants generated in the greatest quantities as shown by the pollutant reduction benefit analysis.

By establishing limitations and standards for certain toxic metal pollutants, dischargers will attain the same degree of control over toxic metal pollutants as they would have been required to achieve had all the toxic metal pollutants been directly limited. This approach is technically justified since the treatable concentrations used for lime precipitation and sedimentation technology are based on optimized treatment for concommitant multiple metals removal. Thus, even though metals have somewhat different theoretical solubilities, they will be removed at very nearly the same rate in a lime precipitation and sedimentation treatment system operated for multiple metals removal. Filtration as part of the technology basis is likewise justified because this technology removes metals non-preferentially.

The same arguments stated above also apply to activated carbon adsorption for the primary aluminum subcategory. Several polynuclear aromatic hydrocarbons were found above treatable concentrations in the primary aluminum subcategory. Since these organic pollutants are structurally similar, the Agency believes that by regulating the toxic organic in the largest quantity, the other toxic organics will be effectively controlled.

The Agency has excluded several toxic organic pollutants from specific regulation in the primary tungsten, primary columbium-tantalum, and secondary silver subcategories because they were found in trace (deminimus quantities) amounts and are neither causing nor likely to cause toxic effects. Table X-3 presents the pollutants selected for specific regulation and Table X-4 presents those pollutants excluded because they are neither causing nor likely to cause toxic effects. Table X-5 presents those pollutants that are effectively controlled by technologies upon which are based other effluent limitations and guidelines. A more detailed discussion on the selection and exclusion of toxic pollutants is presented in Section X of each subcategory supplement.

EXAMPLES OF BUILDING BLOCK APPROACH IN DEVELOPING PERMITS

As an example, consider a facility which combines both aluminum smelting and aluminum forming wastewater and treats this water in a waste treatment system prior to discharge. The facility in this example discharges wastewater from potroom wet air pollution control, direct chill casting, rolling with neat oils, and annealing wet air pollution control. By multiplying the production for each of these operations by the limitations or standards in 40 CFR 421 for potroom wet air pollution control and direct chill casting and 40 CFR 436 for rolling with neat oils and by summing product obtained for each of these waste streams, the permit writer can obtain the allowable mass discharge.

If, for example, the production associated with the potroom wet air pollution system, the production of aluminum reduced, is 200,000 kkg/yr, the production of aluminum resulting from direct chill casting is 150,000 kkg/yr and the rolling with neat oils production is 50,000 kkg/yr, the maximum for any one day limitation based on the best available technology economically achievable (BAT) for the pollutant aluminum is 1,703.15 kg/yr as calculated below:

Potroom Wet Air Pollution Control

(200,000 kkg/yr) (3,954.15 mg/kkg) (10^{-6} kg/mg) = 790.83 kg/yr

Direct Chill Casting

(150,000 kkg/yr) (6,056.97 mg/kkg) (10^{-6} kg/mg) = 908.545 kg/yr

Rolling With Neat Oils

(50,000 kkg/yr) (75.5 mg/kg) (10^{-6} kg/mg) = 3.775 kg/yr

Total = 1,703.15 kg/yr

The Agency recognizes that there may be different technology bases for the limitations and standards applicable to an integrated facility. Continuing with the example from above, the technology basis for BAT for aluminum smelting is lime precipitation, sedimentation, and filtration whereas the technology basis for BAT for aluminum forming is lime precipitation and sedimentation. This does not necessarily imply that the facility install end-of-pipe filtration on all or a part of the discharge flow. EPA developed these limiations based on specified in-plant controls and end-of-pipe treatment technology; however, it does not require that the facility implement these specific in-plant controls and end-of-pipe technology. The facility combining wastewater from manufacturing operations covered by the two categories must install technology and modify the manufacturing operations so as to comply with the mass limitations.

Table X-1

BAT OPTIONS CONSIDERED FOR EACH OF THE NONFERROUS METALS MANUFACTURING SUBCATEGORIES

Subcategory	Options Considered					
	A	B	C	D	E	F
Primary Aluminum	X	X	X	X		X
Secondary Aluminum	X	X	X			X
Primary Copper Electrolytic Refining	X	X	X			X
Primary Zinc	X	X	X	X		X
Primary Lead	X	X	X			X
Secondary Lead	X	X	X	X		X
Primary Tungsten	X	X	X		X	X
Primary Columbium/Tantalum	X	X	X	X	X	X
Secondary Silver	X	X	X		X	X
Metallurgical Acid Plants	X	X	X			X

Table X-2

MODIFICATIONS TO BAT PRECIPITATION EXEMPTION

Subcategory	Existing BAT Regulation		Proposed BAT Regulation	
	Catastrophic Strom	Net Precipitation	Catastrophic Strom	Net Precipitation
Primary Copper Smelting	Yes	Yes	Yes	No
Primary Copper Electrolytic Refining	Yes	Yes	No	No
Secondary Copper	Yes	Yes	Yes	No
Primary Lead	Yes	Yes	No	No

Yes = Regulation contains this allowance.
No = Regulation does not contain this allowance.

Table X-3

REGULATED POLLUTANT PARAMETERS

Subcategory	Pollutant Parameters
Primary Aluminum Smelting	73. benzo(a)pyrene 114. antimony 121. cyanide (Total) 124. nickel aluminum fluoride oil and grease TSS pH
Secondary Aluminum	122. lead 128. zinc aluminum ammonia (N) TSS pH
Primary Electrolytic Copper Refining	120. copper 122. lead 124. nickel TSS pH
Primary Lead	122. lead 128. zinc TSS pH
Primary Zinc	118. cadmium 120. copper 122. lead 128. zinc TSS pH
Metallurgical Acid Plants	115. arsenic 118. cadmium 120. copper 122. lead 128. zinc TSS pH

Table X-3 (Continued)

REGULATED POLLUTANT PARAMETERS

Subcategory	Pollutant Parameters
Primary Tungsten	122. lead
	125. selenium
	128. zinc
	ammonia (N)
	TSS
	pH
Primary Columbium-Tantalum	122. lead
	128. zinc
	ammonia (N)
	fluoride
	TSS
	pH
Secondary Silver	120. copper
	128. zinc
	ammonia (N)
	TSS
	pH
Secondary Lead	114. antimony
	115. arsenic
	122. lead
	128. zinc
	TSS
	pH

Table X-4

TOXIC POLLUTANTS DETECTED BUT ONLY IN TRACE AMOUNTS AND ARE NEITHER CAUSING NOR LIKELY TO CAUSE TOXIC EFFECTS

Subcategory	Pollutants
Primary Tungsten	1. acenaphthene 55. naphthalene 77. acenaphthylene 80. fluorene
Primary Columbium-Tantalum	1. acenaphthene 7. chlorobenzene 8. 1,2,4-trichlorobenzene 10. 1,2-dichloroethane 30. 1,2-trans-dichloroethylene 38. ethylbenzene 56. nitrobenzene 85. tetrachloroethylene
Secondary Silver	4. benzene 6. carbon tetrachloride (tetrachloroemethane) 10. 1,2-dichloroethane 29. 1,1-dichloroethylene 87. trichloroethylene

Table X-5

TOXIC POLLUTANTS EFFECTIVELY CONTROLLED BY TECHNOLOGIES UPON WHICH ARE BASED OTHER EFFLUENT LIMITATIONS AND GUIDELINES

Subcategory	Pollutants
Primary Aluminum Smelting	1. acenaphthene
	39. fluoranthene
	72. benzo (a)anthracene (1,2-benzanthracene)
	76. chrysene
	77. acenaphthylene
	78. anthracene (a)
	79. benzo(ghi)perylene (1,11-benzoperylene)
	80. fluorene
	81. phenanthrene (a)
	82. dibenzo (a,h)anthracene (1,2,5,6-dibenzanthracene)
	84. pyrene
	115. arsenic
	118. cadmium
	119. chromium (Total)
	120. copper
	122. lead
	125. selenium
	128. zinc
	(a) Reported together.
Secondary Aluminum	118. cadmium
Primary Electrolytic Copper Refining	114. antimony
	115. arsenic
	119. chromium (Total)
	125. selenium
	126. silver
	128. zinc
Primary Lead	118. cadmium
	125. selenium

Table X-5 (Continued)

TOXIC POLLUTANTS EFFECTIVELY CONTROLLED BY TECHNOLOGIES UPON WHICH ARE BASED OTHER EFFLUENT LIMITATIONS AND GUIDELINES

Subcategory	Pollutants
Primary Zinc	115. arsenic
	119. chromium (Total)
	124. nickel
	125. selenium
	126. silver
Metallurgical Acid Plants	114. antimony
	119. chromium (Total)
	123. mercury
	124. nickel
	125. selenium
	126. silver
Primary Tungsten	118. cadmium
	119. chromium (Total)
	127. thallium
Primary Columbium-Tantalum	114. antimony
	115. arsenic
	119. chromium (Total)
	120. copper
	124. nickel
	125. selenium
	127. thallium
Secondary Silver	118. cadmium
	119. chromium (Total)
	122. lead
	124. nickel
Secondary Lead	118. cadmium
	119. chromium (Total)
	120. copper
	124. nickel
	126. silver
	127. thallium

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

The basis for new source performance standards (NSPS) under Section 306 of the Clean Water Act is the best available demonstrated technology (BDT). New plants have the opportunity to design the best and most efficient production processes and wastewater treatment technologies. Therefore, BDT includes process changes, in-plant controls (including elimination of wastewater streams), operating procedure changes, and end-of-pipe treatment technologies to reduce pollution to the maximum extent possible. This section describes the control technology for treatment of wastewater from new sources and presents mass discharge limitations of regulated pollutants for NSPS, based on the described control technology.

TECHNICAL APPROACH TO NSPS

All wastewater treatment technologies applicable to a new source in the nonferrous metals manufacturing category have been considered previously for the BAT options. For this reason, six options were considered as the basis for NSPS, all identical to BAT options in Section X. In summary, the treatment technologies considered for new facilities are outlined below:

NSPS Option A is based on:

Lime and settle (chemical precipitation of metals, followed by sedimentation), and, where required

Ammonia steam stripping, and

Oil skimming.

NSPS Option B is based on:

NSPS Option A (lime precipitation and sedimentation), plus process wastewater flow minimization by the following methods:

--Casting contact cooling water recycle
--Air pollution control scrubber liquor recycle

Cyanide precipitation.

NSPS Option C is based on:

NSPS Option B (lime precipitation, sedimentation, and in-process flow reduction), plus multimedia filtration as an effluent polishing step.

NSPS Option D_1 is based on:

> NSPS Option C (lime precipitation, sedimentation, in-process flow reduction, and multimedia filtration), plus activated alumina preliminary treatment for the control of arsenic and fluoride.

NSPS Option D_2 is based on:

> NSPS Option C (lime precipitation, sedimentation, in-process flow reduction, and multimedia filtration), plus activated carbon adsorption preliminary treatment for the control of toxic organics.

NSPS Option E is based on:

> NSPS Option C (lime precipitation, sedimentation, in-process flow reduction, and multimedia filtration), plus end-of-pipe activated carbon adsorption.

NSPS Option F is based on:

> NSPS Option C (lime precipitation, sedimentation, in-process flow reduction, and multimedia filtration), plus reverse osmosis so that all wastewaters can be recycled.

The options listed above are general and can be applied to all subcategories. Wastewater flow reduction within the nonferrous metals manufacturing category is generally based on the recycle of scrubbing liquors and casting contact cooling water. Additional flow reduction is achievable for new sources through alternative process methods which are subcategory-specific. Additional flow reduction attainable for each subcategory is discussed later in this section regarding the NSPS option selection.

For several subcategories, the regulatory production normalized flows for NSPS are the same as the production normalized flows for the selected BAT option. The mass of pollutant allowed to be discharged per mass of product is calculated by multiplying the appropriate treatment effectiveness value (one day maximum and 10-day average values) (mg/l) by the production normalized flows (l/kkg). When these calculations are performed, the mass-based NSPS can be derived for the selected option. Effluent concentrations attainable by the NSPS treatment options are identical to those presented in Section VII.

MODIFICATIONS TO EXISTING NSPS

New source performance standards have been promulgated for the primary and secondary aluminum smelting subcategories. The technology basis for these standards was lime precipitation, sedimentation, and in-process flow reduction of process wastewater. EPA is proposing modifications to these NSPS to incorporate changes proposed for BAT and to include additional flow reductions possible at new sources in the primary aluminum subcategory.

NSPS OPTION SELECTION

In general, EPA is proposing that the best available demonstrated technology for all 12 subcategories in the nonferrous metals manufacturing category be equivalent to BAT technology (NSPS Option C). The principal treatment method for this option is in-process flow reduction, lime precipitation, sedimentation, and multimedia filtration. Option C also includes cyanide precipitation, ammonia steam stripping, and oil skimming, where required. As discussed in Sections IX and X, these technologies are currently used at plants within this point source category. The Agency recognizes that new sources have the opportunity to implement more advanced levels of treatment without incurring the costs of retrofit equipment, and the costs of partial or complete shutdown to install new production equipment. Specifically, the design of new plants can be based on recycle of contact cooling water through cooling towers, recycle of air pollution control scrubber liquor or the use of dry air pollution control equipment. New plants also have the opportunity to consider alternate degassing or slag granulation methods during the preliminary design of the facility.

The data relied upon for selection of NSPS were primarily the data developed for existing sources which included costs on a plant-by-plant basis along with retrofit costs where applicable. The Agency believes that compliance costs could be lower for new sources than the cost estimates for equivalent existing sources, because production processes can be designed on the basis of lower flows and there will be no costs associated with retrofitting the in-process controls. Therefore, new sources will have costs that are not greater than the costs that existing sources would incur in achieving equivalent pollutant discharge reduction. Based on this analysis, the Agency believes that the selected NSPS (NSPS Option C) is an appropriate choice.

Section II of this document presents a summary of the NSPS for the Nonferrous Metals Manufacturing Point Source Category. The pollutants selected for regulation for each subcategory are identical to those selected for BAT. Presented below is a brief discussion describing the technology option selected for NSPS for each subcategory.

PRIMARY ALUMINUM

New source performance standards for primary aluminum are based on BAT plus additional flow reduction. Additional flow reduction is achievable through the use of dry air pollution scrubbing on potlines, anode bake plants, and anode paste plants and elimination of potroom and degassing scrubber discharges. Potroom scrubbing discharges are eliminated by design of efficient potline scrubbing (eliminating potroom scrubbing completely) or 100 percent recycle (with blowdown recycled to casting). Degassing scrubbers are limited by replacing chlorine degassing with inert gases.

These flow reductions are demonstrated at existing plants, but are not included in BAT because they might involve substantial retrofit costs at other existing plants. However, new plants can include these reductions in plant design at no significant additional cost. Dry scrubbing also prevents the contamination of scrubbing discharges with toxic organics, eliminating the need for activated carbon pretreatment included in the proposed BAT to control these toxic organics except for plants discharging wastewater from cathode reprocessing.

The Agency does not believe that the proposed NSPS will provide a barrier to entry for new facilities. In fact, installation of dry scrubbing instead of wet scrubbing in new facilities reduces the cost of end-of-pipe treatment by reducing the overall volume of wastewater discharged and eliminates the need for activated carbon pretreatment proposed for BAT except for process wastewater from cathode reprocessing.

Possible additional pollutant reduction for the primary aluminum subcategory could be accomplished with activated alumina or reverse osmosis. These technologies, however, are not demonstrated in the category nor are they clearly transferable.

SECONDARY ALUMINUM

The technology basis and discharge allowances for NSPS are equivalent to that of the proposed BAT; lime precipitation, sedimentation and filtration. Reverse osmosis, as noted above, is not demonstrated and is not cleary transferable to nonferrous metals manufacturing wastewater. The Agency also does not believe that new plants could achieve any additional flow reduction for chlorine demagging and direct chill casting beyond that proposed for BAT.

PRIMARY COPPER SMELTING

The proposed NSPS for the primary copper smelting subcategory is zero discharge of all process pollutants. The Agency believes that new smelting facilities can be constructed using cooling towers to cool and recirculate casting contact cooling water and slag granulation wastewater instead of large volume cooling impoundments. This technology is also in place in this subcategory. Thus, this proposal eliminates the allowance for the catastrophic precipitation discharge allowed at BAT. The costs associated with construction and operation of a cooling tower system are not significantly greater than those for cooling impoundments, and as such, the Agency does not believe that the proposed NSPS will constitute a barrier for entry of new facilities.

PRIMARY ELECTROLYTIC COPPER REFINING

The proposed NSPS for the primary electrolytic copper refining subcategory are equivalent to BAT (based on BAT Alternative B that includes filtration). Review of the subcategory indicates that no additional demonstrated technologies exist that improve on this BAT technology. Reverse osmosis, as noted above, is not demonstrated and is not clearly transferable to nonferrous metals manufacturing wastewater. The Agency also does not believe that new plants could achieve any additional flow reduction beyond that proposed for BAT.

SECONDARY COPPER

New source performance standards for the secondary copper subcategory are proposed as zero discharge of all process wastewater pollutants. It is believed that new sources can be constructed with cooling towers exclusively and that the cost of cooling towers instead of cooling impoundments is minimal. This eliminates the allowance needed for catastrophic stormwater provided at BAT. Therefore, NSPS, as defined, does not constitute a barrier to entry for new plants.

PRIMARY LEAD

The proposed NSPS prohibits the discharge of all process wastewater pollutants from primary lead smelting. Zero discharge is achievable through complete recycle and reuse of slag granulation wastewater or through slag dumping. Elimination of discharge from slag granulation is demonstrated in six of the seven existing plants, but it is not included at BAT because it would involve substantial retrofit costs for the one existing discharger by requiring the installation of a modified sintering machine. New plants can include elimination of the discharge from the slag granulation process in the plant design at no significant additional cost. Therefore, NSPS does not present any barrier to entry for new plants.

PRIMARY ZINC

New source performance standards for the primary zinc subcategory are proposed equal to BAT. Review of the subcategory indicates that no new demonstrated technologies exist that improve on BAT. Reverse osmosis, as noted above, is not demonstrated in this subcategory and is not clearly transferable to nonferrous metals manufacturing wastewater.

Dry scrubbing is not demonstrated for controlling emissions from zinc reduction furnaces, leaching and product casting. The nature of these emissions (acidic fumes, hot particulate matter) technically precludes the use of dry scrubbers. Therefore, a discharge allowance is included from this source at NSPS equivalent to that proposed for BAT. The Agency does not believe that new plants could achieve any additional flow reduction beyond that proposed for BAT.

METALLURGICAL ACID PLANTS

New source performance standards for the metallurgical acid plants subcategory are proposed equal to BAT. Review of the subcategory indicates that no new demonstrated technologies exist that improve on BAT. Reverse osmosis, as noted above, is not demonstrated in this subcategory and is not clearly transferable to nonferrous metals manufacturing wastewater. The Agency also does not believe that new plants could achieve any additional flow reduction beyond that proposed for BAT.

PRIMARY TUNGSTEN

For the primary tungsten subcategory, NSPS are proposed as equal to BAT. Review of the subcategory indicates that no new demonstrated technologies that improve on BAT exist. Reverse osmosis, as noted above, is not demonstrated in this subcategory and is not clearly transferable to nonferrous metals manufacturing wastewater.

Dry scrubbing is not demonstrated for controlling emissions from acid leaching, APT conversion to oxides and tungsten reduction furnaces. The nature of these emissions (acid fumes, hot particulate matter) technically precludes the use of dry scrubbers. Therefore, a discharge allowance is included for these sources at NSPS equivalent to that proposed for BAT. Also, the Agency does not believe that new plants could achieve any additional flow reduction beyond the 90 percent scrubber effluent recycle proposed for BAT.

PRIMARY COLUMBIUM-TANTALUM

The proposed NSPS for the primary columbium-tantalum subcategory is equivalent to BAT. Review of the subcategory indicates that no new demontrated technologies that improve on BAT exist. Reverse osmosis, as noted above, is not demonstrated in this subcategory and is not clearly transferable to nonferrous metals manufacturing wastewater.

Dry scrubbing is not demonstrated for controlling emissions from concentration digestion, metal salt drying and salt to metal reduction. The nature of these emissions (acidic fumes, hot particulate matter) technically precludes the use of dry scrubbers. Therefore, a discharge allowance is included for these sources at NSPS equivalent to that proposed for BAT. The Agency also does not believe that new plants could achieve any additional flow reduction beyond that proposed for BAT.

SECONDARY SILVER

The proposed NSPS for the secondary silver subcategory is equivalent to BAT (based on BAT Alternative B which includes filtration). Review of the subcategory indicates that no new demonstrated technologies that improve on BAT exist. Reverse osmosis, as noted above, is not demonstrated in this subcategory and is not clearly transferable to nonferrous metals manufacturing wastewater.

Dry scrubbing is not demonstrated for controlling emissions from film stripping, precipitation and filtration of film stripping solutions, precipitation and filtration of photographic solutions, reduction furnaces, leaching and precipitation and filtration. The nature of these emissions (acidic fumes, hot particulate matter) technically precludes the use of dry scrubbers. Therefore, a discharge allowance is included for these sources at NSPS equivalent to that proposed for BAT. The Agency also does not believe that new plants could achieve any additional flow reduction beyond that proposed for BAT.

SECONDARY LEAD

The proposed NSPS for the secondary lead subcategory is equivalent to BAT (based on BAT Alternative B which includes filtration). Review of the subcategory indicates that no new demonstrated technologies that improve on BAT exist. Reverse osmosis, as noted above, is not demonstrated in this subcategory and is not clearly transferable to nonferrous metals manufacturing wastewater.

Dry scrubbing is demonstrated for controlling emissions from kettle smelting. In fact, it is applied so widely throughout this subcategory that it was selected as the best practicable control technology currently available for kettle smelting. Dry scrubbing, however, is not demonstrated for controlling emissions from blast and reverberatory furnaces, and the nature of these emissions (hot particulate matter) precludes the use of dry scrubbing. Therefore, a discharge allowance is included for these sources at NSPS equivalent to that proposed for BAT. The Agency also does not believe that new plants could achieve any additional flow reduction beyond that proposed for BAT.

SECTION XII

PRETREATMENT STANDARDS

Section 307(b) of the Clean Water Act requires EPA to promulgate pretreatment standards for existing sources (PSES), which must be achieved within three years of promulgation. PSES are designed to prevent the discharge of pollutants which pass through, interfere with, or are otherwise incompatible with the operation of publicly owned treatment works (POTW). The Clean Water Act of 1977 adds a new dimension by requiring pretreatment for pollutants, such as heavy metals, that limit POTW sludge management alternatives, including the beneficial use of sludges on agricultural lands. The legislative history of the 1977 Act indicates that pretreatment standards are to be technology-based, analogous to the best available technology for removal of toxic pollutants.

Section 307(c) of the Act requires EPA to promulgate pretreatment standards for new sources (PSNS) at the same time that it promulgates NSPS. New indirect discharge facilities, like new direct discharge facilities, have the opportunity to incorporate the best available demonstrated technologies, including process changes, in-plant controls, and end-of-pipe treatment technologies, and to use plant site selection to ensure adequate treatment system installation.

General Pretreatment Regulations for Existing and New Sources of Pollution were published in the Federal Register, Vol. 46, No. 18, Wednesday, January 28, 1981. These regulations describe the Agency's overall policy for establishing and enforcing pretreatment standards for new and existing users of a POTW and delineates the responsibilities and deadlines applicable to each party in this effort. In addition, 40 CFR Part 403, Section 403.5(b), outlines prohibited discharges which apply to all users of a POTW.

This section describes the treatment and control technology for pretreatment of process wastewaters from existing sources and new sources, and presents mass discharge limitations of regulated pollutants for existing and new sources, based on the described control technology. It also serves to summarize changes from previous rulemakings in the nonferrous metals manufacturing category.

REGULATORY APPROACH

There are 58 facilities, representing 18 percent of the nonferrous metals manufacturing category, who discharge wastewaters to POTW. Pretreatment standards are established to ensure removal of pollutants discharged by these facilities which may interfere with, pass through, or be incompatible with POTW operations. A determination of which pollutants may pass through or be incompatible with POTW operations, and thus be subject to pretreatment standards, depends on the level of treatment used by the POTW. In general, more pollutants will pass through or interfere with a POTW using primary treatment (usually physical separation by settling) than one which has installed secondary treatment (settling plus biological treatment).

Many of the pollutants contained in nonferrous metals manufacturing wastewaters are not biodegradable and are, therefore, not effectively treated by such systems. Furthermore, these pollutants have been known to pass through or interfere with the normal operations of these systems. Problems associated with the uncontrolled release of pollutant parameters identified in nonferrous metals manufacturing process wastewaters to POTW were discussed in Section VI.

The Agency based the selection of pretreatment standards for the nonferrous metals manufacturing category on the minimization of pass-through of toxic pollutants at POTW. For each subcategory, the Agency compared removal rates for each toxic pollutant limited by the pretreatment options to the removal rate for that pollutant at well-operated POTW. The POTW removal rates were determined through a study conducted by the Agency at over 40 POTW and a statistical analysis of the data. (See Fate of Priority Pollutants in Publicly Owned Treatment Works, EPA 440/1-80-301, October, 1980; and Determining National Removal Credits for Selected Pollutants for Publicly Owned Treatment Works, EPA 440/82-008, September, 1982.) The POTW removal rates are presented below:

Toxic Pollutant	POTW Removal Rate
Cadmium	38%
Chromium	65%
Copper	58%
Cyanide	52%
Lead	48%
Nickel	19%
Silver	66%
Zinc	65%
Total Regulated Metals	62%

Other pollutants found in nonferrous metals manufacturing wastewaters include arsenic, antimony, and selenium. There is no data available to EPA concerning POTW removals for these three toxic metals. It was assumed, therefore, that these toxic metals pass through a POTW because they are soluble in water and are not degradable. Specific comments are solicited on the pass-through of these metals and actual POTW removal performance.

A pollutant is deemed to pass through the POTW when the average percentage removed nationwide by well-operated POTW, meeting secondary treatment requirements, is less than the percentage removed by direct dischargers complying with BAT effluent limitations guidelines for that pollutant. (See generally, 46 FR 9415-16 (January 28, 1981).) For example, if the selected PSES option removed 90 percent of the cadmium generated by the subcategory, cadmium would be considered to pass through because a well-operated POTW would be expected to remove 38 percent. Conversely, if the selected PSES option removed only 30 percent of the cadmium generated by the subcategory, it would not be considered to pass through. In the latter case, cadmium would not be selected for specific regulation because a well- operated POTW would have a greater removal efficiency.

The analysis described above was performed for each subcategory starting with the pollutants selected for regulation at BAT. The conventional pollutant parameters (TSS, pH, and oil and grease) and aluminum were not considered for regulation under pretreatment standards. The conventional pollutants are effectively controlled by POTW while aluminum is used to enhance settling. For those subcategories where ammonia was selected for specific limitation, it will also be selected for limitation under pretreatment standards. Most POTW in the United States are not designed for nitrification. Hence, aside from incidental removal, most, if not all, of the ammonia introduced into POTW will pass through into receiving waters without treatment.

An examination of the percent removal for the selected pretreatment options indicated that the pretreatment option selected removed at least 95 percent of the toxic pollutants generated in the nonferrous metals manufacturing point source category. Consequently, the toxics regulated for each subcategory under BAT will also be regulated under pretreatment standards. Table XII-1 presents the pollutants selected for regulation for pretreatment standards.

MODIFICATIONS TO EXISTING PRETREATMENT STANDARDS

Existing pretreatment standards proposed for the nonferrous metals manufacturing category are being revised to incorporate the building block approach as discussed earlier. In addition, information has become available regarding proposed pretreatment standards that warrant revision of promulgated standards.

Primary Aluminum

Pretreatment standards for new sources were promulgated to limit the quantity of fluoride discharged from primary aluminum smelters to POTW. The technology basis for this limitation was based on lime precipitation and sedimentation. PSNS for primary aluminum is being revised to incorporate the building block approach and the technology basis proposed for new sources. Since the PSNS regulation has been proposed, three additional technologies have been identified as demonstrated or transferable to the primary aluminum subcategory. These technologies, filtration, activated carbon, and dry alumina for scrubbing systems, would greatly reduce the amount of toxic pollutants discharged by a new source. A thorough discussion of the building block approach and selection of regulated pollutant parameters is presented in the primary aluminum supplement.

Secondary Aluminum

The promulgated pretreatment for existing secondary aluminum facilities limits the quantity of oil and grease discharged from metal cooling, the pH from demagging fume scrubbers, and the quantity of ammonia discharged from residue milling. These mass limitations are being revised to include additional waste streams that warrant regulations and to upgrade the technology basis so that it is analogous to the proposed BAT.

Pretreatment standards promulgated for new sources require zero discharge of all process generated pollutants into POTW with the exception of demagging fume scrubber liquor. A discharge from this scrubber was allowed only when chlorine is used as a demagging agent. Mass limitations developed for this discharge were based on chemical precipitation and sedimentation technology. Revision of the proposed pretreatment standard is necessary in light of comments and information received and to incorporate the more thorough building block approach. Since the promulgation of PSNS, the secondary aluminum subcategory has reportedly installed direct chill casting processes, which cannot meet zero discharge requirements. An extensive description of the development of these standards can be found in the secondary aluminum supplement.

Secondary Copper

The promulgated pretreatment standards for existing sources allows the discharge of process wastewaters subject to limitations developed from chemical precipitation and sedimentation technology. Currently promulgated BAT limitations, however, require zero discharge of all process wastewaters. Therefore, PSES is being proposed as zero discharge through recycle and reuse making it equivalent to BAT.

OPTION SELECTION

The treatment schemes considered for pretreatment standards for existing sources are identical to those considered for BAT. The treatment schemes considered for pretreatment standards for new sources are also identical to those considered for BAT with the exception of primary aluminum smelting and primary lead where additional flow reduction is required. Each of the options considered builds upon the BPT technology basis of chemical precipitation and sedimentation. Depending on the pollutants present in the subcategories raw wastewaters, a combination of the treatment technologies listed below were considered:

- Option A = Lime precipitation, sedimentation, ammonia steam stripping, and cyanide removal.
- Option B = Option A (lime precipitation, sedimentation, ammonia steam stripping, and cyanide precipitation), plus flow reduction.
- Option C = Option B (lime precipitation, sedimentation, ammonia steam stripping, cyanide precipitation, and flow reduction), plus multimedia filtration.
- Option D_1 = Option C (lime precipitation, sedimentation, ammonia steam stripping, cyanide precipitation, flow reduction, and multimedia filtration), plus activated alumina.
- Option D_2 = Option C (lime precipitation, sedimentation, ammonia steam stripping, cyanide precipitation, flow reduction, and multimedia filtration), plus activated carbon preliminary treatment.
- Option E = Option C (lime precipitation, sedimentation, ammonia steam stripping, cyanide precipitation, flow reduction, and multimedia filtration), plus activated carbon at end-of-pipe treatment.
- Option F = Option C (lime precipitation, sedimentation, ammonia steam stripping, cyanide precipitation, flow reduction, and multimedia filtration), plus reverse osmosis.

A more complete discussion of the treatment technologies considered is presented in Section X regarding the selection of BAT treatment technologies. The general approach taken by the Agency for pretreatment standards for this category is presented below. The mass-based standards for each subcategory may be found in Section II of this document. The options selected for the category on which to base pretreatment standards are discussed below.

Primary Aluminum

Pretreatment standards for existing sources will not be proposed for the primary aluminum smelting subcategory since there are no existing indirect dischargers.

The technology basis for PSNS is identical to NSPS and includes flow reduction, lime precipitation, sedimentation, and filtration for control of toxic metals and fluoride; activated carbon pretreatment for toxic organics removal; and cyanide precipitation pretreatment.

Secondary Aluminum

The technology basis for PSES is lime precipitation and sedimentation, ammonia steam stripping, and filtration. The achievable concentration for ammonia steam stripping is based on iron and steel manufacturing category data. Flow reduction is based on the same zero discharge of scrubber effluent for scrap drying wet air pollution control which is equivalent to the flow basis of BAT. Only one indirect discharger uses a wet system to control air emissions from scrap drying, and it does not practice any recycle for this system. Ammonia steam stripping and lime precipitation and sedimentation, and filter technologies are presently demonstrated in the subcategory. Ammonia air stripping was the technology basis for the promulgated PSES. Steam stripping is proposed instead of air stripping because it is a superior technology in that it does not transfer the pollutant from one media to another.

As an alternative to mass-based standards, a POTW may elect to implement concentration-based standards for the secondary aluminum subcategory. The purpose of mass-based standards is to encourage recycle and reuse of process wastewaters. Since there is no additional flow reduction from current practices to the regulatory flows used to develop the mass-based standards, concentration-based standards are an appropriate way to ensure pollutant reduction for this subcategory.

Implementation of the proposed PSES would remove annually an estimated 1,214 kg of toxic pollutants over estimated raw discharges. Capital cost for achieving proposed PSES is $2.4 million, and annual cost of $1.6 million.

The technology basis used to develop standards for new sources is identical to those used for existing sources. There is no demonstrated technology that is better than the PSES technology because the only other flow reduction technology available, reverse osmosis, is neither demonstrated nor clearly transferable to this subcategory.

Primary Copper Smelting

No pretreatment standards for existing sources are proposed for the primary copper smelting subcategory since there are no existing indirect dischargers.

The technology basis for proposed PSNS is identical to NSPS (and BAT), which is zero discharge of all process wastewater pollutants, with no allowance for catastrophic stormwater discharge. New indirect dischargers will be constructed with cooling towers, not cooling impoundments, since they will be located near POTW, suggesting that they will be near heavily populated areas where land is scarce making the cost of acquiring land to install an impoundment relatively high. Thus, we do not believe there are any incremental costs associated with PSNS.

Primary Electrolytic Copper Refining

No pretreatment standards for existing sources are proposed for the primary electrolytic copper refining subcategory since there are no existing indirect dischargers.

The technology basis of pretreatment for new sources is based on lime precipitation, sedimentation, filtration, and 90 percent recycle for casting contact cooling water. As in NSPS, all other waste streams generated at copper refineries are not included in the flow allowance. Flow reduction for new sources is feasible, based on reverse osmosis because reverse osmosis is not demonstrated in the nonferrous metals manufacturing category nor it is clearly transferable.

Secondary Copper

As mentioned earlier in this section, PSES for secondary copper is being modified to make it equivalent to BAT, or zero discharge. Implementation of the proposed PSES would remove annually an estimated 4,837 kg of toxic pollutants from raw discharges. Furthermore, it is anticipated that the costs associated with installation and operation of cooling towers and holding tanks for indirect dischargers to achieve zero discharge will be insignificant.

The technology basis for proposed PSNS is identical NSPS, PSES, and BAT. No allowance for catastrophic stormwater discharges is provided as is discussed in Chapter XI for NSPS.

Primary Lead

No pretreatment standards for existing sources are proposed for the primary lead subcategory since there are no existing indirect dischargers.

The technology basis for proposed PSNS is equivalent to NSPS or zero discharge. As discussed in Chapter XI for NSPS, slag removed from blast furnaces contains economical recoverable amounts of lead that are granulated before recycling. New facilities will have the opportunity to install dry slag conditioning devices to eliminate the usage of wastewater in this process or implement a 100 percent recycle system of slag granulation wastewater.

Primary Zinc

No pretreatment standards for existing sources are proposed for the primary zinc subcategory since there are no existing indirect dischargers.

The technology basis for proposed pretreatment standards for new sources is equivalent to NSPS or flow reduction, lime precipitation, sedimentation, and filtration. The PSNS flow allowances are based on minimization of process wastewater wherever possible through the use of cooling towers to recycle contact cooling water and sedimentation basins for wet scrubbing wastewater. The discharges from contact cooling and scrubbers is based on 90 percent recycle. No additional flow reduction for new sources is feasible because the only other available flow reduction technology, reverse osmosis, is not demonstrated nor is it clearly transferable to this subcategory. Elimination of wastewater from scrubbers by installing dry scrubbers is not demonstrated for controlling emissions from zinc reduction furnaces, leaching and product casting. Th nature of emissions from these sources (acidic fumes, hot particulate matter) technically precludes the use of dry scrubbers.

Metallurgical Acid Plants

Pretreatment standards for existing sources are not proposed for metallurgical acid plants. There is only one existing indirect discharger, and its estimated current mass discharge is less than the level that would be achieved by indirect dischargers with BAT-equivalent technology (lime precipitation and sedimentation, flow reduction, and filtration). Consequently, the Agency believes that the amount of pollutants discharged by this plant are too insignificant to justify developing PSES.

The proposed technology basis for pretreatment for new sources is equivalent to NSPS or flow reduction, lime precipitation, sedimentation, and filtration. There is no demonstrated technology that provides better pollutant removal than that proposed for PSNS. The acid plant blowdown allowance allocated for PSNS is based on 90 percent recycle. The Agency believes that no additional flow reduction is feasible for new sources because the only other available flow reduction technology, reverse osmosis, is not demonstrated nor is it clearly transferable for this subcategory.

Primary Tungsten

The technology basis for PSES is equivalent to BAT or wastewater flow reduction, lime precipitation and sedimentation, ammonia steam stripping, and filtration. Flow reduction is based on 90 percent recycle of scrubber effluent that is the flow basis of BAT. This flow rate is achieved by one of the three indirect dischargers in the subcategory, and filters are demonstrated at one indirect discharger.

Implementation of the proposed PSES limitations would remove an estimated 4,075 kg/yr of toxic pollutants over estimated raw discharge, and an estimated 79,530 kg/yr of ammonia. Capital cost for achieving proposed PSES is $.396 million, and annual cost of $.329 million. The intermediate option considered for PSES was Option B which is equivalent to the selected PSES technology without filters.

The technology basis for proposed PSNS is identical to PSES. The PSES flow allowances are based on minimization of process wastewater wherever possible through the use of cooling towers to recycle contact cooling water and sedimentation basins for wet scrubbing wastewater. These discharges are based on 90 percent recycle of these waste streams. No additional flow reduction for new sources is feasible because the only other flow reduction technology, reverse osmosis, is not demonstrated nor is it clearly transferable for this subcategory. (See Section XII of the primary tungsten supplement.) Dry scrubbing is not demonstrated for controlling emissions from acid leaching, APT conversion to oxides and tungsten reduction furnaces. The nature of these emissions (acidic fumes, hot particulate matter) technically precludes the use of dry scrubbers. The only other end-of-pipe technology, activated carbon, does not significantly reduce toxic pollutant discharges while increasing costs ten-fold.

Primary Columbium-Tantalum

The technology basis for proposed PSES is equivalent to BAT or wastewater flow reduction, lime precipitation and sedimentation, ammonia steam stripping, and filtration. Flow reduction is based on 90 percent recycle of scrubber effluent that is the flow basis of BAT. This flow rate is achieved by both indirect dischargers in the subcategory, and filters are demonstrated at direct dischargers in this subcategory.

Implementation of the proposed PSES limitations would remove 64,890 kg/yr of toxic pollutants and 8,808 kg/yr of ammonia from raw discharges. Capital cost for achieving proposed PSES is $2.47 million, and annual cost of $1.41 million.

The technology basis for proposed PSNS is identical to NSPS, PSES and BAT. There is no known economically feasible, demonstrated technology that is better than PSES technology. The PSES flow allowances are based on minimization of process wastewater wherever possible through the use of cooling towers to recycle contact cooling water and sedimentation basins for wet scrubbing wastewater. The discharges are based on 90 percent recycle of these waste streams. No additional flow reduction for new sources is feasible because the only other available flow reduction technology, reverse osmosis, is not demonstrated nor is it clearly transferable for this subcategory. Dry scrubbing is not demonstrated for controlling emissions from concentration digestion, metal salt drying and salt to metal reduction. The nature of these emissions (acidic fumes, hot particulate matter) technically precludes the use of dry scrubbers.

Secondary Silver

For PSES, two alternative standards are proposed. As stated in more detail in Section X of the Secondary Silver Supplement, the secondary silver subcategory is experiencing structural economic changes not anticipated in this analysis. Consequently, this analysis does not adequately reflect the ability of the tolling segment of the industry to achieve economically proposed standards based on filtration. Filtration is, however, demonstrated in the secondary silver subcategory, removes additional toxic pollutants, and it appears economically achievable based on the existing economic analysis.

The technology basis for Alternative A is in-process flow reduction, lime precipitation and sedimentation, and ammonia steam stripping. Wastewater flow reduction is based on increased recycle of leaching scrubber water, furnace scrubber water and casting contact cooling water. Flow reduction is demonstrated for each of these unit operations in the subcategory, while chemical precipitation and sedimentation is currently in place at seven plants in the secondary silver subcategory. Implementation of Alternative A would remove an estimated 9,731 kg/yr of toxic pollutants and 1,500 kg/yr over current estimated discharges. The estimated capital cost for achieving this option is $1.03 million; the estimated annualized cost is $0.958 million.

Alternative B is equivalent to Alternative A with the addition of filtration as an effluent polishing step. Wastewater flow reduction is based on increased recycle of leaching scrubber water, furnace scrubber water and casting contact cooling water. Flow reduction is demonstrated for each of these unit operations in the subcategory. Filtration is currently in place at three discharging plants in the secondary silver subcategory. Alternative B would remove annually an estimated 1,561 kg of toxic pollutants over estimated current discharge, and it would remove 9,792 kg of toxic pollutants generated by the industry. For both options, an estimated 149,300 kg of ammonia above estimated current discharges is removed. Capital cost for achieving proposed PSES Alternative B is $1.14 million, with an annual cost of $1.07 million.

The proposed technology basis for PSNS is equivalent to NSPS or in-process flow reduction, lime precipitation and sedimentation, filtration, and ammonia steam stripping. Review of the subcategory indicates that no new demonstrated technologies that improve on this BAT technology exist. Reverse osmosis, as noted above, is not demonstrated in this subcategory and is not clearly transferable to nonferrous metals manufacturing wastewater.

Dry scrubbing is not demonstrated for controlling emissions from film stripping, precipitation and filtration of film stripping solutions, precipitation and filtration of photogrpahic solutions, reduction furnaces, leaching and precipitation and filtration. The nature of these emissions (acidic fumes, hot particulate matter) technically precludes the use of dry scrubbers. Therefore, an allowance is included for these sources at PSES equivalent to that proposed for BAT and PSES. The Agency also does not believe that new plants could achieve any additional flow reduction beyond that proposed for BAT.

Secondary Lead

Two alternative pretreatment standards are proposed for existing sources. As stated in Section X of the Secondary Lead Supplement, the secondary lead subcategory is experiencing long-run market shifts which may affect the structure and composition of this subcategory. Because these shifts have definite impacts on the subcategory, the current econoimc analysis may not reflect the ability of secondary lead plants to achieve standards based on filtration. Filtration is, however, demonstrated by seven facilities in the secondary lead subcategory.

The technology basis for Alternative A is lime precipitation and sedimentation preceded by wastewater flow reduction. Flow reduction is based on 90 percent recycle of scrubber effluent and casting contact cooling water, and is achieved by two of the 16 indirect dischargers. Implementation of Alternative A removes an estimated 2,470 kg of toxic pollutants over estimated raw discharge. The estimated capital cost of this technology is $1.49 million, with an estimated annual cost of $0.56 million.

The technology basis for Alternative B is equivalent to Alternative A plus filtration. Implementation of the proposed Alternative B PSES would remove annually an estimated 2,625 kg of toxic pollutants over estimated raw discharge. Removals over estimated raw discharge are approximately 17,290 kg of toxic pollutants. Capital cost for achieving proposed PSES Alternative B is $3.04 million, with an annual cost of $1.94 million.

Pretreatment standards for new sources are equivalent to NSPS or wastewater flow reduction, lime precipitation, sedimentation and filtration. Flow reduction is based on 90 percent recycle of scrubber effluent and casting contact cooling water using cooling towers and holding tanks. There is no known demonstrated technology that is better than the technology basis proposed for new secondary lead plants. Furthermore, no additional flow reduction for new sources is feasible because the only other available flow reduction technology, reverse osmosis, is not demonstrated for this subcategory, nor is it clearly transferable. Dry scrubbing is not demonstrated for controlling emissions from blast and reverberatory furnaces, and the nature of these emissions (hot particulate matter) precludes the use of dry scrubbing.

Table XII-1

REGULATED POLLUTANT PARAMETERS

Subcategory	Pollutant Parameters
Primary Aluminum Smelting	73. benzo(a)pyrene
	114. antimony
	121. cyanide (Total)
	124. nickel
	fluoride
Secondary Aluminum	122. lead
	128. zinc
	ammonia (N)
Primary Electrolytic Copper Refining	120. copper
	122. lead
	124. nickel
Primary Lead	122. lead
	128. zinc
Primary Zinc	118. cadmium
	120. copper
	122. lead
	128. zinc
Metallurgical Acid Plants	115. arsenic
	118. cadmium
	120. copper
	122. lead
	128. zinc
Primary Tungsten	122. lead
	125. selenium
	128. zinc
	ammonia (N)
Primary Columbium-Tantalum	122. lead
	128. zinc
	ammonia (N)
	fluoride
Secondary Silver	120. copper
	128. zinc
	ammonia (N)
Secondary Lead	114. antimony
	115. arsenic
	122. lead
	128. zinc

SECTION XIII

BEST CONVENTIONAL POLLUTANT CONTROL TECHNOLOGY

The 1977 amendments to the Clean Water Act added Section 301(b)(2)(E), establishing "best conventional pollutant control technology" (BCT) for discharge of conventional pollutants from existing industrial point sources. Biochemical oxygen-demanding pollutants (BOD_5), total suspended solids (TSS), fecal coliform, oil and grease (O&G), and pH have been designated as conventional pollutants (see 44 FR 44501).

BCT is not an additional limitation, but replaces BAT for the control of conventional pollutants. In addition to the other factors specified in Section 304(b)(4)(B), the Act requires that limitations for conventional pollutants be assessed in light of a two-part cost-reasonableness test. On October 29, 1982, the Agency proposed a revised methodology for carrying out BCT analyses (47 FR 49176). The purpose of the proposal was to correct errors in the BCT methodology originally established in 1977.

Part 1 of the proposed BCT test requires that the cost and level of reduction of conventional pollutants by industrial dischargers be compared with the cost and level of reduction to remove the same type of pollutants by publicly-owned treatment works (POTW). The POTW comparison figure has been calculated by evaluating the change in costs and removals between secondary treatment (30 mg/l BOD and 30 mg/l TSS) and advanced secondary treatment (10 mg/l BOD and 10 mg/l TSS). The difference in cost is divided by the difference in pounds of conventional pollutants removed, resulting in an estimate of the "dollars per pound" of pollutant removed, that is used as a benchmark value. The proposed POTW test benchmark is $0.30 per pound (1978 dollars). The annual incremental cost for each subcategory to remove conventional pollutants beyond BPT is calculated as:

$$\frac{[(\text{Candidate BCT Annual Cost}) - (\text{BPT Annual Cost})]}{[(\text{Candidate BCT Conventional Pollutants Removed}) - (\text{BPT Conventional Pollutants Removed})]}$$

Part 2 of the BCT test requires that the cost and level of reduction of conventional pollutants by industrial dischargers be evaluated internally to the industry. In order to develop a benchmark that assesses a reasonable relationship between cost and removal, EPA has developed an industry cost ratio which compares the dollar per pound of conventional pollutant removed in going from primary to secondary treatment levels with that of going from secondary to more advanced treatment levels. The basis of costs for the calculation of this ratio are the costs incurred by a POTW. EPA used these costs because: they reflect

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the treatment technologies most commonly used to remove conventional pollutants from wastewater; the treatment levels associated with them compare readily to the levels considered for industrial dischargers; and the costs are the most reliable for the treatment levels under consideration. The proposed industry subcategory benchmark is 1.42. If the industry figure for a subcategory is lower than 1.43, the subcategory passes the BCT test. This ratio is calculated as:

$$\frac{\text{Total Annual Cost/Pound Removed (BPT to BCT)}}{\text{Total Annual Cost/Pound Removed (pre-BPT to BPT)}}$$

The Agency usually considers two conventional pollutants in the cost test, TSS and an oxygen-demanding pollutant. Although both oil and grease and BOD_5 are considered to be oxygen-demanding substances by EPA (see 44 Fed. Reg. 50733), only one can be selected in the cost analysis to conform to procedures used to develop POTW costs. Oil and grease is used rather than BOD_5 in the cost analysis performed for nonferrous metals manufacturing waste streams due to the common use of oils in casting operations in this industry.

BPT is the base for evaluating limitations on conventional pollutants (i.e., it is assumed that BPT is already in place). The test evaluates the cost and removals associated with treatment and controls in addition to that specified as BPT.

If the conventional pollutant removal cost of the candidate BCT is less than the POTW cost, Part 1 of the cost-reasonableness test is passed and Part 2 (the internal industry test) of the cost-reasonableness test must be performed. If the internal industry test is passed, then a BCT limitation is promulgated equivalent to the candidate BCT level. If all candidate BCT technologies fail both parts of the cost-reasonableness test, the BCT requirements for conventional pollutants are equal to BPT.

The BCT test was performed on the 10 subcategories with direct dischargers and the results are summarized in Table XIII-1. The cost test was not required for primary copper smelting and secondary copper since these subcategories have promulgated BPT effluent limitations requiring zero discharge of process wastewater pollutants. All of the 10 subcategories failed Part 1 of the test for both the proposed BAT and intermediate options, eliminating the need for testing in Part 2. Consequently, BCT is equivalent to BPT in all subcategories.

Table XIII-1

SUMMARY OF BCT TEST IN THE NONFERROUS METALS MANUFACTURING CATEGORY

Subcategory	Comparable POTW Benchmark	Incremental Cost Proposed BAT (Part 1)	Proposed BAT Option Part 1 (Pass or Fail)	Incremental Cost Intermediate Option (Part 1)	Proposed Intermediate Option Part 1 (Pass or Fail)
Primary Aluminum	$0.27	$ 3.07	Fail	2.20	Fail
Secondary Aluminum	$0.27	$ 15.68	Fail	--	Fail
Primary Electrolytic Copper Refining	$0.27	$ 5.07	Fail	22.06	Fail
Primary Lead	$0.27	$ 13.26	Fail	0.0	Fail
Primary Zinc	$0.27	$ 8.20	Fail	4.30	Fail
Metallurgical Acid Plants	$0.27	$ 19.60	Fail	23.77	Fail
Primary Tungsten	$0.27	$ 15.04	Fail	19.73	Fail
Primary Columbium-Tantalum	$0.27	$ 76.16	Fail	8.73	Fail
Secondary Silver	$0.27	$ 4.09	Fail	1,700	Fail
Secondary Lead	$0.27	$179.94	Fail	15.34	Fail

SECTION XIV

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SECTION XVI

GLOSSARY

This section is an alphabetical listing of technical terms (with definitions) used in this document which may not be familiar to the reader.

4-AAP Colorimetric Method

An analytical method for total phenols and total phenolic compounds that involves reaction with the color developing agent 4-aminoantipyrine.

Acidity

The quantitative capacity of aqueous solutions to react with hydroxyl ions. Measured by titration with a standard solution of a base to a specified end point. Usually expressed as milligrams per liter of calcium carbonate.

The Act

The Federal Water Pollution Control Act Amendments of 1972 as amended by the Clean Water Act of 1977 (PL 92-500).

Amortization

The allocation of a cost or account according to a specified schedule, based on the principal, interest and period of cost allocation.

Analytical Quantification Level

The minimum concentration at which quantification of a specified pollutant can be reliably measured.

Anglesite

A mineral occurring in crystalline form or as a compact mass.

Antimonial Lead

An alloy composed of lead and up to 25 percent antimony.

Backwashing

The operation of cleaning a filter or column by reversing the flow of liquid through it and washing out matter previously trapped.

Baghouses

The area for holding bag filters, an air pollution control equipment device.

Ball Mill

Pulverizing equipment for the grinding of raw material. Grinding is done by steel balls, pebbles, or rods.

Barton Process

A process for making lead oxide to be used in secondary lead oxide batteries. Molten lead is fed, agitated, and stirred in a pot with the resulting fine droplets oxidized. Material is collected in a settling chamber where crystalline varieties of lead oxide are formed.

Batch Treatment

A waste treatment method where wastewater is collected over a period of time and then treated prior to discharge. Treatment is not continuous, but collection may be continuous.

Bench Scale Pilot Studies

Experiments providing data concerning the treatability of a wastewater stream or the efficiency of a treatment process conducted using laboratory-size equipment.

Best Available Demonstrated Technology (BADT)

Treatment technology upon new source performance standards as defined by Section 306 of the Act.

Best Available Technology Economically Achievable

Level of technology applicable to toxic and nonconventional pollutants on which effluent limitations are established. These limitations are to be achieved by July 1, 1984 by industrial discharges to surface waters as defined by Section 301(b)(2)(C) of the Act.

Best Conventional Pollutant Control Technology (BCT)

Level of technology applicable to conventional pollutant effluent limitations to be achieved by July 1, 1984 for industrial discharges to surface waters as defined in Section 301(b)(2)(E) of the act.

Best Management Practices (BMP)

Regulations intended to control the release of toxic and hazardous pollutants from plant runoff, spillage, leaks, solid waste disposal, and drainage from raw material storage.

Best Practicable Control Technology Currently Available (BPT)

Level of technology applicable to effluent limitations to have been achieved by July 1, 1977 (originally) for industrial discharges to surface waters as defined by Section 301(b)(1)(A) of the Act.

Betterton Process

A process used to remove bismuth from lead by adding calcium and magnesium. These compounds precipitate the bismuth which floats to the top of the molten bath where it can be skimmed from the molten metal.

Billet

A long, round slender cast product used as raw material in subsequent forming operations.

Biochemical Oxygen Demand (BOD)

The quantity of oxygen used in the biochemical oxidation of organic matter under specified conditions for a specified time.

Blast Furnace

A furnace for smelting ore concentrates. Heated air is blown in at the bottom of the furnace, producing changes in the combustion rate.

Blister Copper

Copper with 96 to 99 percent purity and appearing blistered; made by forcing air through molten copper matte.

Blowdown

The minimum discharge of circulating water for the purpose of discharging dissolved solids or other contaminants contained in the water, the further buildup of which would cause concentration in amounts exceeding limits established by best engineering practice.

Calcining

Heating to a high temperature without fusing so as to remove material or make other changes.

Carbon Reduction

The process of using the carbon of coke as a reducing agent in the blast furnace.

Cementation

A proces in which metal is added to a solution to initiate the precipitation of another metal. For example, iron may be added to a copper sulfate solution to precipitation Cu:

$$CuSO_4 + Fe \rightarrow Cu + FeSO_4$$

Cerussite

A mineral occurring in crystalline form and made of lead carbonate.

Charged

Material that has been melted by being placed inside a furnace.

Charging Scrap

Scrap material put into a furnace for melting.

Chelation

The formation of coordinate covalent bonds between a central metal ion and a liquid that contains two or more sites for combination with the metal ion.

Chemical Oxygen Demand (COD)

A measure of the oxygen-consuming capacity of the organic and inorganic matter present in the water or wastewater.

Cold-Crucible Arc Melting

Melting and purification of metal in a cold refractory vessel or pot.

Colloid

Suspended solids whose diameter may vary between less than one micron and fifteen microns.

Composite Samples

A series of samples collected over a period of time but combined into a single sample for analysis. The individual samples can be taken after a specified amount of time has passed (time composited), or after a specified volume of water has passed the sampling point (flow composited). The sample can be automatically collected and composited by a sampler or can be manually collected and combined.

Consent Decree (Settlement Agreement)

Agreement between EPA and various environmental groups, as instituted by the United States District Court for the District of Columbia, directing EPA to study and promulgate regulations for the toxic pollutants (NRDC, Inc. v. Train, 8 ERC 2120 (D.D.C. 1976), modified March 9, 1979, 12 ERC 1833, 1841).

Contact Water

Any water or oil that comes into direct contact with the aluminum, whether it is raw material, intermediate product, waste product, or finished product.

Continuous Casting

A casting process that produces sheet, rod, or other long shapes by solidifying the metal while it is being poured through an open-ended mold using little or no contact cooling water. Thus, no restrictions are placed on the length of the product and it is not necessary to stop the process to remove the cast product.

Continuous Treatment

Treatment of waste streams operating without interruption as opposed to batch treatment. Sometimes referred to as flow-through treatment.

Contractor Removal

Disposal of oils, spent solutions, or sludge by a commercial firm.

Conventional Pollutants

Constitutents of wastewater as determined by Section 304(a)(4) of the Act, including but not limited to pollutants classified as biological-oxygen-demanding, oil and grease, suspended solids, fecal coliforms, and pH.

Converting

The process of blowing air through molten metal to oxidize impurities.

Cooling Tower

A hollow, vertical structure with internal baffles designed to break up falling water so that it is cooled by upward-flowing air and the evaporation of water.

Copper Matte

An impure sulfide mixture formed by smelting the sulfide ores in copper.

Cupelled

Refined by means of a small shallow porous bone cup that is used in assaying precious metals.

Cupola Furnace

A vertical cylindrical furnace for melting materials on a small scale. This furnace is similar to a reverberatory furnace but only on a smaller scale.

Cyclones

A funnel-shaped device for removing particulates from air or other fluids by centrifugal means.

Data Collection Portfolio (dcp)

The questionnaire used in the survey of the aluminum forming industry.

Degassing

The removal of dissolved hydrogen from the molten aluminum prior to casting. This process also helps to remove oxides and impurities from the melt.

Direct Chill Casting

A method of casting where the molten aluminum is poured into a water-cooled mold. The base of this mold is the top of a hydraulic cylinder that lowers the aluminum first through the mold and then through a water spray and bath to cause solidification. The vertical distance of the drop limits the length of the ingot. This process is also known as semi-continuous casting.

Direct Discharger

Any point source that discharges to a surface water.

Dore

Gold and silver bullion remaining in a cupelling furnace after oxidized lead is removed.

Dross

Oxidized impurities occurring on the surface of molten metal.

Drying Beds

Areas for dewatering of sludge by evaporation and seepage.

Effluent

Discharge from a point source.

Effluent Limitation

Any standard (including schedules of compliance) established by a state or EPA on quantities, rates, and concentrations of chemical, physical, biological, and other constituents that are discharged from point sources into navigable waters, the waters of the contiguous zone, or the ocean.

Electrolysis

A method of producing chemical reactions by sending electric current through electrolytes or molten salt.

Electrolytic Refining

A purification process in which metals undergo electrolysis.

Electrolytic Slime

Insoluble impurities removed from the bottom of an electrolytic cell during electrolytic refining.

Electron Beam Melting

A melting process in which an electron beam is used as a heating source.

Electrostatic Precipitator (ESP)

A gas cleaning device that induces an electrical charge on a solid particle which is then attracted to an oppositely charged collector plate. The collector plates are intermittently vibrated to discharge the collected dust to a hopper.

End-of-Pipe Treatment

The reduction of pollutants by wastewater treatment prior to discharge or reuse.

Film Stripping

Separation of silver-bearing material from scrap photographic film.

Fluid Bed Roaster

A type of roaster in which the material is suspended in air during roasting.

Fluxes

Substances added to molten metal to help remove impurities and prevent excessive oxidation, or promote the fusing of the metals.

Galena

A bluish gray mineral occurring in the form of crystals, masses, or grains; it constitutes the principal ore of lead.

Gangue

Valueless rock and mineral mined with ore. When separated from ore, the material is known as "slag."

Gas Chromatography/Mass Spectroscopy (GC/MS)

Chemical analytical instrumentation used for quantitative organic analysis.

Grab Sample

A single sample of wastewater taken without regard to time or flow.

Hardeners

Master alloys that are added to a melt to control hardness.

Harris Process

A process in which sodium hydroxide and sodium nitrate are added to molten lead to soften or refine it. These two compounds react with impurities in the molten metal forming a slag that floats to the top of the molten metal.

Humidification Chamber

A chamber in which the water vapor content of a gas is increased.

Hydrogenation

The addition of hydrogen to a molecule.

Hydrometallurgical

The use of wet processes to treat metals.

Indirect Discharger

Any point source that discharges to a publicly owned treatment works.

Inductively-Coupled Argon Plasma Spectrophotometer (ICAP)

A laboratory device used for the analysis of metals.

Ingot

A large, block-shaped casting produced by various methods. Ingots are intermediate products from which other products are made.

In-Process Control Technology

Any procedure or equipment used to conserve chemicals and water throughout the production operations, resulting in a reduction of the wastewater volume.

Litharge

A yellowish compound with a crystalline form; also known as lead monoxide.

Matte

A metal sulfide mixture produced by smelting sulfide ores.

Mitsubishi Process

A process used in primary copper refining which incorporates three furnaces to combine roasting, smelting, and converting into one continuous proces. The Mitsubishi process results in reduced smelting rates and heating costs.

New Source Performance Standards (NSPS)

Effluent limitations for new industrial point sources as defined by Section 306 of the Act.

Nonconventional Pollutant

Parameters selected for use in performance standards that have not been previously designated as either conventional or toxic pollutants.

Non-Water Quality Environmental Impact

The ecological impact as a result of solid, air, or thermal pollution due to the application of various wastewater technologies to achieve the effluent guidelines limitations. Also associated with the non-water quality aspect is the energy impact of wastewater treatment.

NPDES Permits

Permits issued by EPA or an approved state program under the National Pollution Discharge Elimination System.

Off-Gases

Gases, vapors, and fumes produced as a result of an aluminum forming operation.

Oil and Grease (O&G)

Any material that is extracted by freon from an acidified sample and that is not volatilized during the analysis, such as hydrocarbons, fatty acids, soaps, fats, waxes, and oils.

Outokumpu Furnaces

A furnace used for flash smelting, in which hot sulfide concentrate is fed into a reaction shaft along with preheated air and fluxes. The concentrate roasts and smelts itself in a single autogeneous process.

Parke's Process

A process in which zinc is added to molten lead to form insoluble zinc-gold and zinc-silver compounds. The compounds are skimmed and the zinc is removed through vacuum de-zincing.

Pelletized

An agglomeration process in which an unbaked pellet is heat hardened. The pellets increase the reduction rate in a blast furnace by improving permeability and gas-solid contact.

pH

The pH is the negative logarithm of the hydrogen ion activity of a solution.

Pollutant Parameters

Those constituents of wastewater determined to be detrimental and, therefore, requiring control.

Precipitation Supernatant

A liquid or fluid forming a layer above precipitated solids.

Priority Pollutants

Those pollutants included in Table 2 of Committee Print number 95-30 of the "Committee on Public Works and Transportation of the House of Representatives," subject to the Act.

Process Water

Water used in a production process that contacts the product, raw materials, or reagents.

Production Normalizing Parameter (PNP)

The unit of production specified in the regulations used to determine the mass of pollution a production facility may discharge.

PSES

Pretreatment standards (effluent regulations) for existing sources.

PSNS

Pretreatment standards (effluent regulations) for new sources.

Publicly Owned Treatment Works (POTW)

A waste treatment facility that is owned by a state or municipality.

Pug Mill

A machine for mixing and tempering a plastic material by the action of blades revolving in a drum or trough.

Pyrometallurgical

The use of high-temperature processes to treat metals.

Raffinate

Undissolved liquid mixture not removed during solvent refining.

Recycle

Returning treated or untreated wastewater to the production process from which it originated for use as process water.

Reduction

A reaction in which there is a decrease in valence resulting from a gain in electrons.

Reuse

The use of treated or untreated process wastewater in a different production process.

Reverberatory Furnaces

Rectangular furnaces in which the fuel is burned above the metal and the heat reflects off the walls and into the metal.

Roasting

Heating ore to remove impurities prior to smelting. Impurities within the ore are oxidized and leave the furnace in gaseous form.

Rod

An intermediate aluminum product having a solid, round cross section 9.5 mm (3/8 inches) or more in diameter.

Rotary Furnace

A circular furnace which rotates the workpiece around the axis of the furnace during heat treatment.

Scrubber Liquor

The untreated wastewater stream produced by wet scrubbers cleaning gases produced by aluminum forming operations.

Shot Casting

A method of casting in which molten metal is poured into a vibrating feeder, where droplets of molten metal are formed through perforated openings. The droplets are cooled in a quench tank.

Sintering

The process of forming a bonded mass by heating metal powders without melting.

Skimmings

Slag removed from the surface of smelted metal.

Slag

The product of fluxes and impurities resulting from the smelting of metal.

Smelting

The process of heating ore mixtures to separate liquid metal and impurities.

Soft Lead

Lead produced by the removal of antimony through oxidation. The lead is characterized by low hardness and strength.

Spent Hypo Solution

A solution consisting of photographic film fixing bath and wash water which contains unreduced silver from film processing.

Stationary Casting

A process in which the molten aluminum is poured into molds and allowed to air-cool. It is often used to recycle in-house scrap.

Subcategorization

The process of segmentation of an industry into groups of plants for which uniform effluent limitations can be established.

Supernatant

A liquid or fluid forming a layer above settled solids.

Surface Water

Any visible stream or body of water, natural or man-made. This does not include bodies of water whose sole purpose is wastewater retention or the removal of pollutants, such as holding ponds or lagoons.

Surfactants

Surface active chemicals that tend to lower the surface tension between liquids.

Sweating

Bringing small globules of low-melting constituents to an alloy surface during heat treatment.

Total Dissolved Solids (TDS)

Organic and inorganic molecules and ions that are in true solution in the water or wastewater.

Total Organic Carbon (TOC)

A measure of the organic contaminants in a wastewater. The TOC analysis does not measure as much of the organics as the COD or BOD tests, but is much quicker than these tests.

Total Recycle

The complete reuse of a stream, with makeup water added for evaporation losses. There is no blowdown stream from a totally recycled flow and the process water is not periodically or continuously discharged.

Total Suspended Solids (TSS)

Solids in suspension in water, wastewater, or treated effluent. Also known as suspended solids.

Traveling Grate Furnace

A furnace with a moving grate that conveys material through the heating zone. The feed is ignited on the surface as the grate moves past the burners; air is blown in the charge to burn the fuel by downdraft combustion as it moves continuously toward discharge.

Tubing Blank

A sample taken by passing one gallon of distilled water through a composite sampling device before initiation of actual wastewater sampling.

Tuyeres

Openings in the shell and refractory lining of a furnace through which air is forced.

Vacuum Dezincing

A process for removing zinc from a metal by melting or heating the solid metal in a vacuum.

Venturi Scrubbers

A gas cleaning device utilizing liquid to remove dust and mist from process gas streams.

Volatile Substances

Materials that are readily vaporizable at relatively low temperatures.

Wastewater Discharge Factor

The ratio between water discharged from a production process and the mass of product of that production process. Recycle water is not included.

Water Use Factor

The total amount of contact water or oil entering a process divided by the amount of aluminum product produced by this process. The amount of water involved includes the recycle and makeup water.

Wet Scrubbers

Air pollution control devices used for removing pollutants as the gas passes through the spray.

Zero Discharger

Any industrial or municipal facility that does not discharge wastewater.

The following sources were used for defining terms in the glossary:

Gill, G. B., Nonferrous Extractive Metallurgy. John Wiley & Sons, New York, NY, 1980.

Lapedes, Daniel N., Dictionary of Scientific and Technical Terms, 2nd edition. New York, NY, McGraw-Hill Book Co., 1978.

McGannon, Harold E., The Making, Shaping, and Treating of Steel, 9th edition. Pittsburgh, PA, U.S. Steel Corp., 1971.

METRIC UNITS

CONVERSION TABLE

MULTIPLY (ENGLISH UNITS)		by		TO OBTAIN (METRIC UNITS)
ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilo
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555(°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
ton (short)	ton	0.907	kkg	metric ton (1000 kilog
yard	yd	0.9144	m	meter

* Actual conversion, not a multiplier

* U.S. GOVERNMENT PRINTING OFFICE: 1983 381-545/3817